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THE RISK OF COLLISION ASSESSMENT WITH GRAPHIC FORMS OF TARGET DATA PRESENTATION USE

ABSTRACT

Guarantee of the ship safety is the primary task posed for modern navigation systems. This concerns monitoring the proper ship position as well as providing accurate information about the collision threat. The proper interpretation of this information belongs to the navigator. He must take into account many variables affecting the assessment of the situation and then make the right decision regarding anti-collision manoeuvres. This assessment could be made easier for him with use some form of graphic target data presentation methods other than currently required and described in IMO performance standards. Other possible graphic presentation methods of collision information are described in the article along with the concept of their usage.

Keywords:
ARPA, safety of navigation, tracking, target data presentation, IMO performance standards.

1. INTRODUCTION

Radar systems with automatic target tracking are still the main systems used for gathering information about the risk of collision and allow information analysis, anti-collision manoeuvres planning and their effectiveness monitoring. The main advantage of these systems in collision avoidance is possibility of use sea stabilized true target data. The problem of proper stabilization mode use in collision avoidance was presented in [Juszkiewicz, 2014]. Keep this in mind because of the similarity of AIS information presented on the radar/navigation screens. CPA and TCPA values are calculated at similar accuracy both in ARPA and AIS, however true target movement parameters are only ground stabilized in AIS. It could be especially confusing if two types of information about the target true motion from two different systems are simultaneously presented on one screen (some targets are tracked by radar and for the other the AIS information is presented). This combination of information should be especially avoided during navigation with strong currents.

Performance standards for radar equipment can be found mainly in Chapter V of the SOLAS Convention1974 (with amendments coming into effect in subsequent editions of the Convention) and the IMO Resolutions (depending on the date of installation of the radar equipment on board Resolution A.422 (XI), A.823 (19) or MSC.192 (79) should be taken into consideration).

The vector presentation is the basic graphic method of target data presentation on radar screens. This type of presentation is obligatory and often only available possibility of target data presentation. This type of presentation is well understood by navigators because of the history of radars use in collision avoidance and plotting use for target tracking. Developed rules of the use of vector information collision avoidance also proved themselves in systems with automatic target tracking. Proper on-screen data interpretation was not a problem for navigators who changed traditional radar to ARPA despite of the fact that ARPA vectors indicate future target positions instead of past plotting information. The time equal vector length rule for all presented vectors and possibility of easy vector type switching (true or relative) are the main advantages of this presentation in ARPA.

This method of data presentation is simple and effective, however in more complicated navigational situation (dense traffic areas) could not be effective considering collision avoidance.

The systematic tracking capabilities increase from 10 to 20 and finally to 40 targets [IMO Res. A.422(XI),1979][IMO Res. A.823(19, 1995][Res. MSC 192(79), 2004] should also rise the safety level. However, as soon as navigator can/must acquire more targets they start to complain about less clarity of presented information and difficulties in interpretation. It could be the reason of wrong decision making which will generate next collisions or dangerous situations. In that case, for a better clarity, navigators very often decrease the vectors time parameter and reduce the number of acquired targets only for the closest ones during navigation in heavy traffic. It could lead to too late response for dangerous situations, especially when *CPA/TCPA Warning* parameters are improperly configured.

Therefore, care must follow the development of the concept of other graphic methods of collision situation presentation on the radar screen. Combining information from multiple target tracking and their presentation in the form which accelerate the situation analysis while reducing the error probability should be the next stage of radar equipment development.

Such different methods of presentation were and still are allowed by radar performance standards. Examples of these solutions are available in multiple radar devices. An interesting Potential Area of Danger (PAD) concept developed by Sperry is of course worth mentioning. Another good example is Sector of Danger (SOD) concept which was implemented in polish ARPA RADWAR 01. Because of various reasons, these ideas did not become popular but they are still an interesting alternative for the traditional vector display.

Use of method different from vector presentation must of course give more effective situation assessment and easier way of taking effective action, otherwise there will be no point in using it. Therefore, such variants of graphic method presentation should be considered which do not reduce target detection, do not mask radar picture and let to display integrated information for all targets.

2. GRAPHIC TARGET DATA PRESENTATION METHODS.

As it was already mentioned, the basic way of target motion presentation on the radar screen is a vector form. It has unquestionable strong points (simple interpretation, common use, true and relative motion easy switching, easy to adapt for different circumstances). However, this type of information could be less clear in heavy traffic navigation so that collision avoidance could be then more difficult. So it could be considered to use other graphic method of target data presentation. Other methods such presentation may include the ability to display:

- Predicted Points of Collision (PPC);
- Potential Area of Danger (PAD);
- Sector of Danger (SOD);
- Dangerous Passing Areas (DPA);
- Dangerous courses Sector (DCS).

Like the vector presentation each of these methods will have its advantages and disadvantages.

2.1 Predicted Points of Collision (PPC)

Predicted Points of Collision function indicate possible collision positions assuming that tracked target (TRGT) will proceed at present course and speed while own ship (OS) will approach collision point at present speed [Bole et all, 2005][Galor, 2016]. In this type of presentation the most dangerous courses could be determined but there is no information about safety courses to obtain CPA_{limit}.

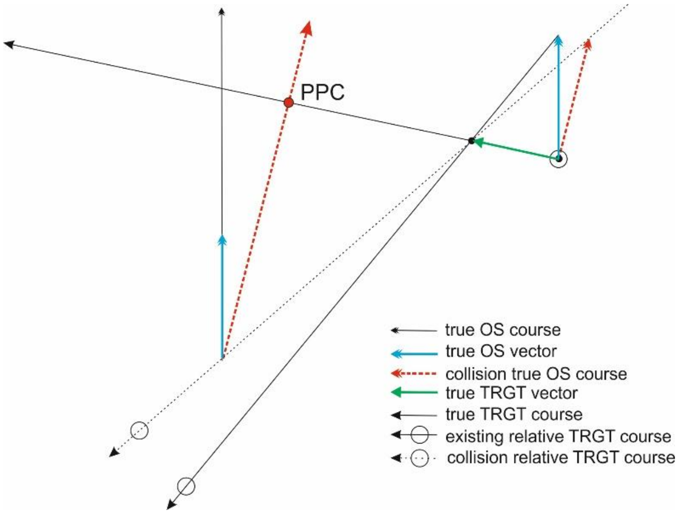

Figure 1. The example if only one PPC can be determined (Vw>Vo). Source: Author.

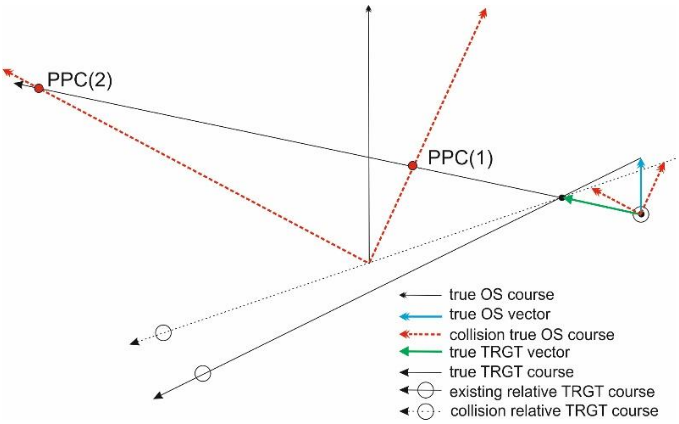

Figure 2. The example if two PPCs are determined (Vw<Vo). Source: Author

PPCs (if they are) will always be presented on the true target course line and their numbers will depend on OS and TRGT speed relation. If OS speed is lower than TRGT speed (Vw<Vo) there could be a situation that there is no PPC, or there could exist only one or two PPCs (Figure 2). If Vw>Vo there is always only one PPC (Figure1) [Bole et all, 2005][Galor, 2016].

2.2 Potential Area of Danger (PAD

Potential Areas of Danger is some wider form of PPC idea. There is CPA_{limit} value taken additionally into consideration except all assumptions of PPC calculation method. Of course, the CPA_{limit} value depends on many factors which should be taken into consideration. The main of them are: OS size and type, its manoeuvreability, visibility, traffic density etc.

The concept of PAD drawing is shown in Figure 3.

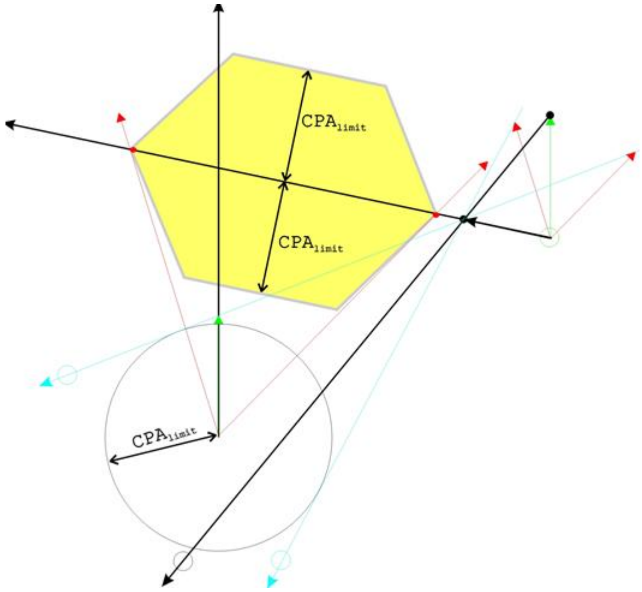

Figure 3. The principle of PAD determination and use (on the basis of [Bole et all, 2005]).

The base of this method is to safely determine OS true courses in order to obtain safety passing distance. Next step is to determine PADs border points. They are in points of OS true safety courses intersection with TRGT true course. PAD's hexagons are drawn between border points. They always stretch along TRGT true course line. The anti-collision PADs using is based on the rule that safety OS course must pass outside all existing PADs. This will ensure the achievement of a safe passing distance.

This method lets to determine required anti-collision course change but there is no possibility of determining required speed alternation. When OS speed changes also PADs size and position is changing. In this situation it is not possible to predict these PADs changes

A lot of additional lines and shapes on the screen (especially in dense traffic navigation) is another disadvantage of this method. Because of this target detection could be seriously decreased.

2.3 Sectors of dangers (SOD)

Another graphic targets data presentation are Sectors of Danger. This method lets to determine both speed and course of sufficient manoeuvres. The idea of that method is presented in Figure 4 and was described in detail in [Bole et all, 2005].

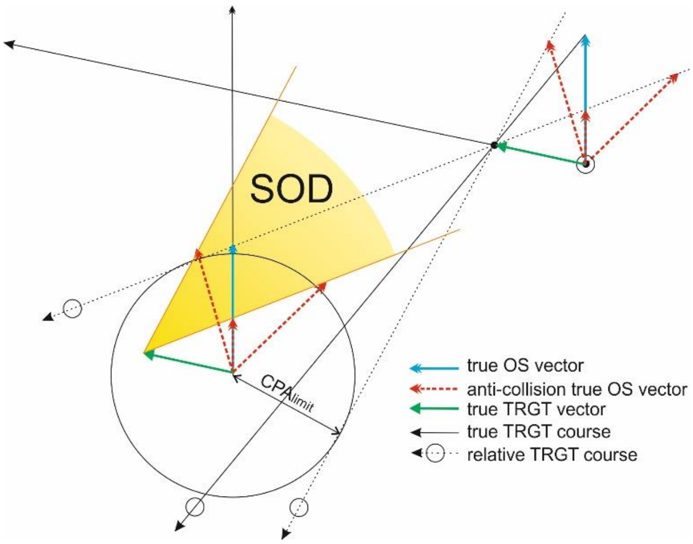

Figure 4. The principle of PAD determination and use (on the basis of [Bole et all, 2005]).

SODs are displayed near OS position and Vector Time parameter is taken into account. In this case (unlike as with PAD) the most important is not only OS head line direction but the end of OS true vector position. Planned anti-collision manoeuvre should provide such an OS vector change (in direction or length) to move the OS true vector end outside of displayed SODs. It is easy to imagine that also in this case, when more target are tracked, radar picture is also obscured near OS position.

2.4 Dangerous Passing Areas (DPA)

The idea of Dangerous Passing Areas is slightly similar to PAD conception but in this case border points of real dangerous areas are calculated instead of PAD border points. These border points are calculated using OS movement parameters, TRGT data and CPA_{limit} value. During their calculation next predicted position of OS and TRGT are calculated as well (Figure 5).

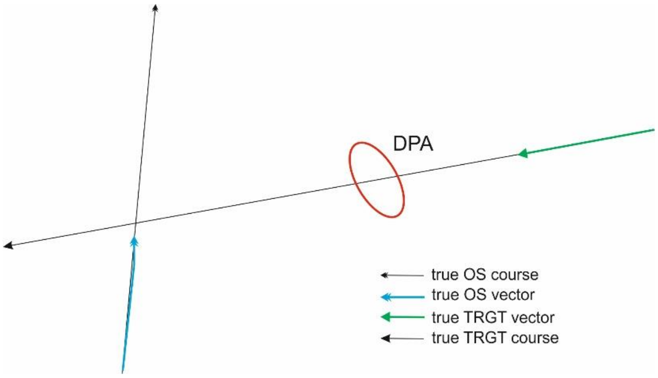

Figure 5. An example of the Dangerous Passing Area (DPA) presentation. Source: Author.

There are different results of DPA calculation (similar like in PAD and PPC cases) possible depending on OS and TRGT true speed relations. The concept of such a graphic presentation will be described in details in the next part of paper.

The most complicated situation arises of course when OS true speed is lower than TRGT true speed. There could be calculated two, one or no dangerous areas. In the specific case two dangerous areas may merge and inside of this DPA two PPC could be calculated. The interpretation of DPA is similar to PAD, OS heading line should be outside of DPA.

2.5 Sectors of Dangerous Courses (DCS)

The main advantage of this type of presentation is an easy information fusion. Information for all tracked targets could be presented in one place. Usage of this type of information should be simple, because it could be presented anywhere on the screen (it may depend on navigator preferences) and is concentrated so radar picture should be clear and not additionally noised.

The border points of DCSs could be calculated both on the PAD or DPA base. The second case is presented in Figure 6.

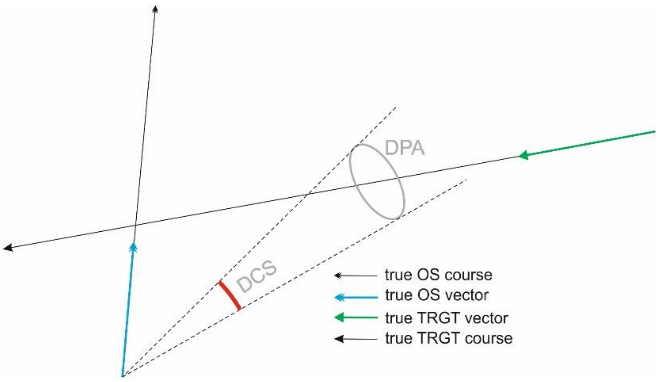

Figure 6. The DCS drawing on the DPA base. Source: Author.

The Danger Courses Sector could be displayed:

- in the distance equal to OS true vector length;
- in the distance equal to 2/3 of OS true vector length;
- on the bearing scale (around radar picture).

It seems that the latter concept fulfill both the terms of a good presentation and an easy interpretation.

THE REAL DPA CALCULATION

Real dangerous passing areas could be defined as the set of all positions reachable by OS for which predicted CPA values are equal or less CPA_{limit}. The CPA_{limit} value depends on many factors which were described in paragraph 2.2. This value couldn't be too small or the OS safety will not be provided. On the other hand, too high and inadequate value causes excessive risk areas drawing and it doesn't meet effectiveness condition for threat warning activation.

Following assumptions for DPA drawing should be introduced:

- OS true speed Vw=const.;
- TRGT true speed Vo=const.;
- TRGT true course KRo=const.;
- TRGT position (BRG, $Dist$);
- CPA_{limit} value.

In principle DPA counting comes to border points position calculation when $CPA=CPA_{limit}$. For achieving this, common points of two circles should be calculated:

- the ring of OS positions after t (fixed position of the circle center, the variable radius of the circle);
- the ring of CPA_{limit} radius value and circle center in TRGT position after t (the variable position of the circle center, the fixed value of the circle radius).

This situation is shown in Figure 7.

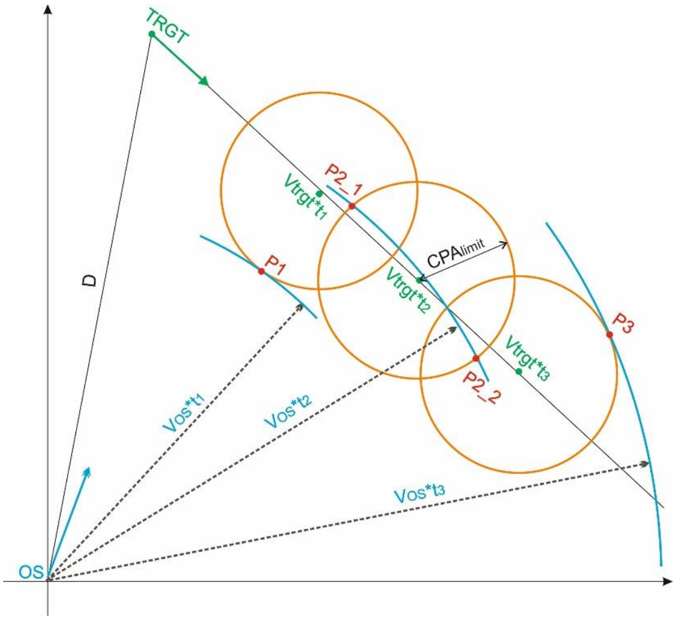

Figure7. The principle of DPA border points calculation. Source: Author.

In the Figure 7 the green points are TRGT positions after t_1, t_2 and t_3 period. Orange circles indicate CPA_{limit} distance from TRGT positions. In these moments OS could reach blue rings (respectively $VOS*t_1$, $VOS*t_2$ and $VOS*t_3$). The beginning (point *P1*) and the end (point *P3*) of DPA drawing are the moments of pre-defined circles tangency. Points *P2_1* and *P2_2* are calculated when pre-defined circles are crossing.

The main parameters used at crossing points calculation (*P2_1* and *P2_2*) are presented in Figure 8 and used formulas in equations (1)-(7).

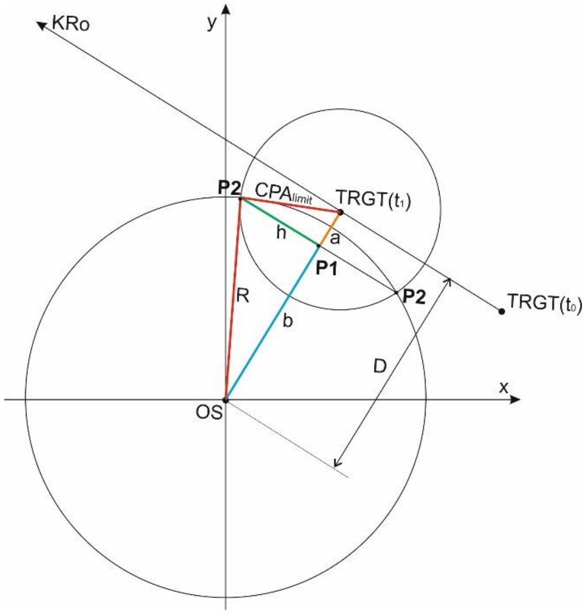

Figure 8. DPA border points presentation (crossing circles case). Source: Author.

Because:

$$h^2 = CPA_{limit}^2 - a^2 \quad \text{and} \quad h^2 = R^2 - b^2 \tag{1}$$

$$a = \frac{(CPA_{limit}^2 - R^2 + D^2)}{2D} \tag{2}$$

$$b = \frac{(R^2 - CPA_{limit}^2 + D^2)}{2D} \tag{3}$$

$$P1x = x_{TRGT} + \frac{a(x_{OS} - x_{TRGT})}{D} \tag{4}$$

$$P1y = y_{TRGT} + \frac{a(y_{OS} - y_{TRGT})}{D} \tag{5}$$

Circles crossing point's coordinates are:

$$P2x = P1x \pm \frac{h(y_{OS} - y_{TRGT})}{D} \tag{6}$$

$$P2y = P1y \mp \frac{h(x_{OS} - x_{TRGT})}{D} \tag{7}$$

where:

x_{TRGT}, y_{TRGT} - predicted TRGT position coordinates after t_1;
x_{OS}, y_{OS} - OS position coordinates;
$P1x$, $P1y$ - $P1$ coordinates;
$P2x$, $P2y$ - $P2$ coordinates;

It should be noted that if $D>CPA_{limit}+R$ there is no DPA. Similarily to PAD case (according to ships relation) it is possible to count 1, 2 or none DPA. Examples of such cases are presented in Figures 9-11.

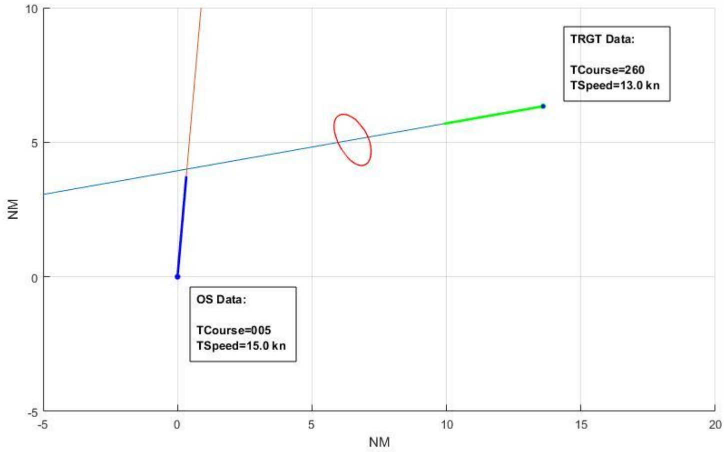

Figure 9. An example when only one DPA exists (VOS>VTRGT). Source: Author.

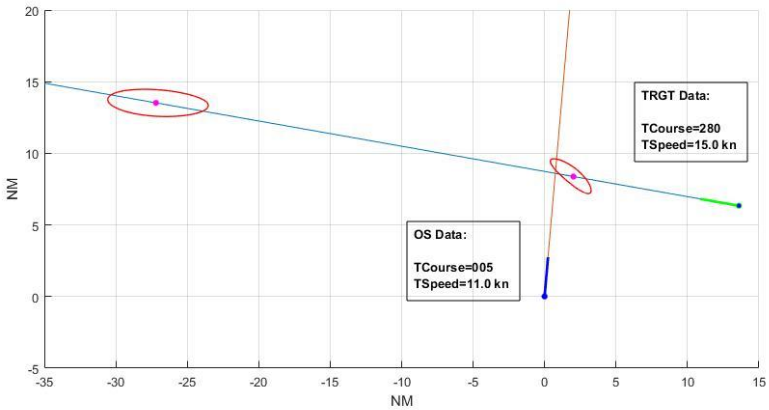

Figure 10. An example when two DPAs and two PPCs exist (VOS<VTRGT).
Source: Author.

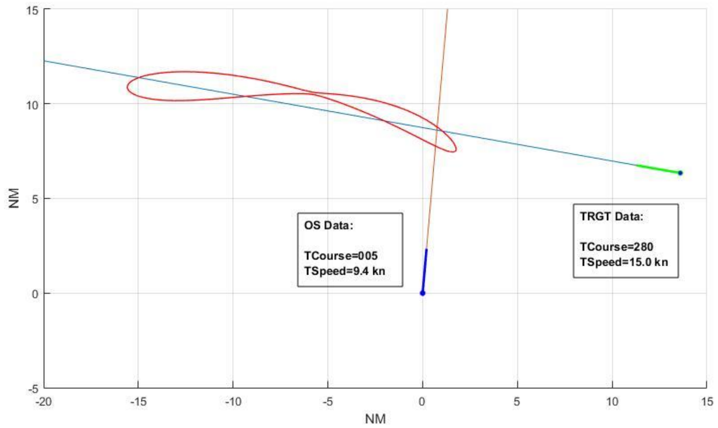

Figure 11. An example when two DPAs start to merge into one ($V_{OS}<V_{TRGT}$).
Source: Author.

CONCLUSIONS

Chosen (other than vectors) graphic methods of target data presentation were presented in the paper. Advantages and disadvantages of these methods were also highlighted. Then the method of Dangerous Passing Areas was described in details.

An analysis of new possibilities of data presentation shows that they could be a good alternative to vector presentation, especially in congested areas. There is only one main requirement. They could not shade the radar picture and impede target detection.

The PAD and (described in details) DPA are similar. In second case real dangerous areas are calculated. The main advantages of both methods are easy interpretation and possibility of anti-collision manoeuvre planning. Of course they allow to plan only safety course change but not speed but they give to navigators' possibility of quick situation assessment and anti-collision avoidance.

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STRESZCZENIE

Podstawowym zadaniem stawianym przed nowoczesnymi systemami nawigacyjnymi jest zapewnienie bezpieczeństwa statku. Dotyczy to zarówno konieczności właściwej kontroli pozycji statku jak i dostarczenia rzetelnej informacji o zagrożeniu kolizyjnym. Właściwa interpretacja tej informacji należy do nawigatora. Musi on uwzględnić wiele zmiennych czynników mających wpływ na ocenę sytuacji, a następnie podjąć właściwą decyzję odnośnie podejmowanych manewrów antykolizyjnych. Możliwość zastosowania innej formy graficznej prezentacji informacji niż wymagana obecnie przez przepisy może ułatwić mu taka ocenę. W artykule przedstawione zostały inne sposoby graficznej prezentacji informacji kolizyjnej wraz z koncepcją ich wykorzystania.