Combination of navigational and VDRbased information to enhance alert management

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ABSTRACT: Within this paper results of ongoing investigations will be presented. Main subject of studies is laid on the present situation of alert management onboard ships navigational bridges and potential use of data recorded with mandatory ship-borne VDR equipment during normal ship operation to support the process of on board collision avoidance. The investigations and results discussed and presented in the paper are gained within trhe work in two different projects on research and technical development. The first is the European MARNIS – project on Maritime Navigation and Information Services. It is funded by the European Commission, Department for Energy and Transport. Secondly some of the results presented here are part of investigations performed under the national RD project "Maritime Safety Assistance Rostock" which is funded by the German Ministry of Education and Research Berlin.

1 INTRODUCTION

Safe navigation, including collision and grounding avoidance, is the overall task of the navigating officer in charge. The global aim is to ensure the safe transport of goods during a ship's voyage from port of departure to port of destination. Modern ship bridges are highly-automated man-machine systems. Safety and efficiency of the ship operations are dependent, as in all other complex man-machine systems, on the communication between humans and machines during the accomplishment of tasks. Humans can fulfil their assigned monitoring, control, and decision tasks most effectively, if the information flow between them and machines is adapted to the human skills and abilities (e.g. Brainbridge (1983) and Lützhöft, 2004).

In the last years a strong increase of modern information systems on the ship bridges could be observed. Simple displays and control systems were supplemented or replaced by complex computer-based information systems. Information of different sensors and systems are combined in integrated navigation systems (INS). In order to support the mariner effectively on board, a task- and situation-dependent presentation of the information is a compellingly need.

With the enlarged number of systems and sensors onboard, and the increase of automation a proliferation of alarm signals on the bridge is associated. Alarm signals coming from various systems and sensors sometimes lead to a confusing and difficult manageable situation for the mariner, which is distracting him from his task to safely navigate the vessel. Redundant and superfluous audible and visual alarm announcements are appearing on the bridge.

The International Maritime Organization (IMO) IMO has recognised this situation and decided to revise the exiting standards for INS and to develop requirements for an alarm management system. A working group coordinated by Germany was established to progress this work. Further activities as especially the eNavigation (Earthy, 2006a) initiative is strongly linked to thise subject and covers problems related to integration of systems.

Several investigations were performed to analyse the specific situation on board ships regarding the occurrence of alarms by means of a series of empirical studies. Basing on the gained results and taking into consideration existing drafts for enhanced alert management a concept was drafted for the specific task of collision avoidance as a first approach. The concept covers a technical combination of different sensor information together with the use of data recorded by VDR systems to contribute to the reduction of the high number of alarms and warnings presently observed on board of ships.

The investigations were partly performed under the framework of a national Research and Development project funded by the German Ministry of Transport Building and Urban Affairs, and under the European MarNIS – project, funded by the European Commission, Department for Energy and Transport (Willems & Glansdorp, 2006).

2 PRESENT SITUATION

2.1 *Integrated Navigation Systems*

According to the existing IMO Performance Standards a integrated navigation systems (INS) is defined as a system that supports safety of navigation by evaluating inputs from several independent and different sensors, combining them to provide information giving timely warnings of potential dangers and degradation of integrity of this information. By now three different categories A, B and C of INS are established. The lowest level INS category A has as a minimum to provide the information of position, speed, heading and time, each clearly marked with an indication of integrity. The second level category INS (B), is defined as a system that automatically, continually and graphically indicates the ship’s position, speed and heading and, where available, depth in relation to the planned route as well as to known and detected hazards. Finally INS(C), is a system that provides means to automatically control heading, track or speed and monitor the performance and status of these controls.

The definitions and categories are under reviewing presently. One aim of the work of the IMO Correspondence Group reviewing the standard is, to elaborate a more generic definition and start with a totally new functional approach, where tasks and functions will use as the basis for INS definition. In future INS will be defined as such, if it performs at least two of the navigational tasks route monitoring, collision avoidance and track control. Of course further navigational tasks may also be integrated to such systems. Additionally an alert management system should become a mandatory part of a future INS and is specified in the draft standard in a separate chapter.

Table 1. Required mandatory IMO alarms for selected navigational devices

INS component / Device	Number of mandatory alarms
Heading Control	
System	3
Track Control	
System	10
ECDIS	7
Radar	5
GNSS	7
Echo sounder	2
Gyro compass	3
Bridge watch	1
alarm	2
AIS	6
VDR	2

A inventory looking at the required navigational alerts was performed and the result is summarized in Table 1.

2.2 *Analysis of alarm management*

In the frame of different projects a series of several empirical studies were performed to analyse the present state. These studies were aimed at the improvement of ship borne alarm management of INS. It was started with a review of kind and types of alarm messages implemented to navigations systems. Considering the technical integration of the relative new Automatic Identification System (AIS) the situation is summarized in the following figure. It can be seen, that the number of implemented alarm messages to increases rapidly with the interconnection to other navigation systems and the level of integration consequently.

Moreover the example shows, that the number of real alarm messages implemented to the systems is much more higher than the number of required mandatory IMO alarms. The number of potential alarms and the design of alarm systems in general seems to be a problem (Earthy, 2006b).

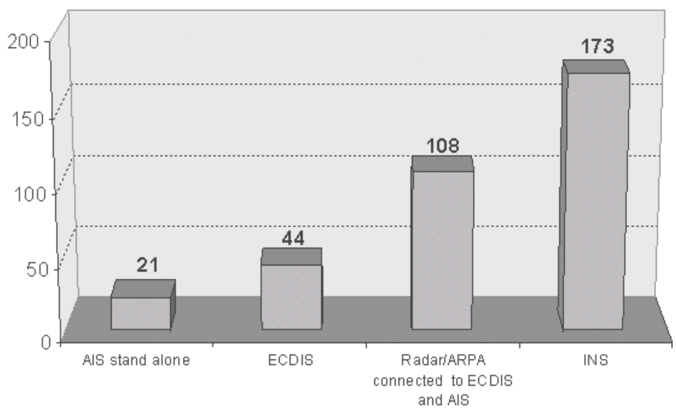

Fig. 1. Number of technical alarm messages implemented to selected stand alone and connected systems

Further for this purpose real alarm situations on board of vessels were continuously recorded (e.g. Lepsoe & Eide, 2005). Interviews and questionnaires with experts were used additionally to collect data about operational needs of the navigators (Motz & Baldauf, 2007).

With respect to kind and frequency of alarms a great variety was detected. A discussion of the gained results showed that strong correlations are indicated in respect to the area related navigational situations (open sea, coastal area and confined waters). As one of the main reasons it was found, that the implemented alarm algorithms are fixed, as, e.g., collision warnings, having no suitable technical option to adapt automatically alarming to changing conditions of a navigational situation. Figure 2 illustrates this result exemplarily.

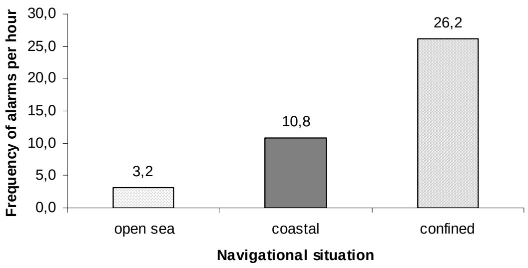

Fig. 2. Average frequency of alarms depending on sea areas for a voyage of a passenger vessel

On the other hand all the studies have also shown a great dependency of the alarm rates on the specific navigation devices integrated on the bridges. As can be seen from the example given in Figure 3 the majority of alarms were registered at the radar device and were dangerous target alarms mainly.

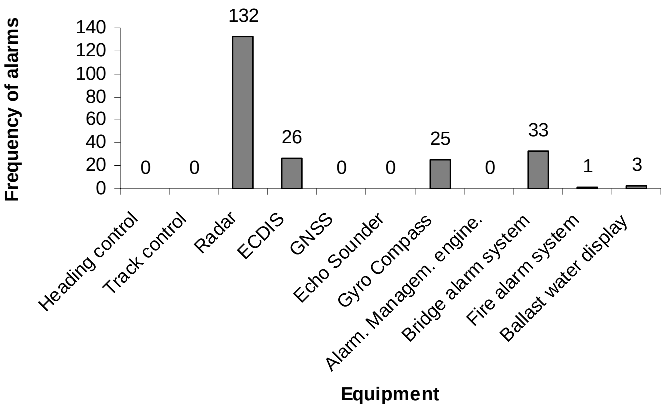

Fig. 3. Frequency of alarms per device

Basing on the results it has been concluded, that a future alarm management should harmonize the operation, handling, distribution and presentation of alerts. To avoid the uncontrolled increase of alarms, a set of priorities based on urgency of the required response is needed to improve the operator's situation awareness and his ability to take effective action. Therefore a new philosophy is suggested for the prioritization and categorization of alarms. Alert is defined as umbrella term for the indication of any abnormal situation with three different priorities of alerts:

- Alarm (highest priority) - immediate awareness and action required;
- warning - awareness of changed condition;
- caution - awareness of condition which does not warrant an alarm or warning condition, but still requires attention out of the ordinary consideration of the situation or of given information.

The three priorities should be indicated visual and acoustically in different ways.

To categorize the alerts further, the following two alert categories are specified at the moment.

- navigational alerts - functional indication of dangerous situation, e.g., collision warning, depth warning;
- technical alerts - equipment failure or loss.

Basic concepts for improvement of collision warnings are already available but has to be further researched and developed. Investigations should be dedicated to apply the concept according to a functional approach for new alarm management.

Finally, the alert management HMI should be integrated to support the bridge team in the immediate identification of any abnormal situation, including the source and reason for the abnormal situation and in its decisions for the necessary actions. The alert management HMI should be provided at least at the position from where the vessel is navigated and fulfil two major functions: indicating and identifying alerts, allowing the acknowledgment of alerts by the bridge team.

2.3 *Case study of a real collision scenario*

A couple of real situations were investigated to analyse the present situation regarding the operational integration of AIS for the purposes of collision avoidance and to identify potential existing technical lacks and problems as a basis for better integration of this new technology into the navigation process on board. One example of a collision scenario is used her to highlight some aspects of integration.

The tracks depicted in Figure 4 belongs to an example of a scenario happened in open sea area with a traffic separation scheme during night time and conditions of good to moderate visibility. Four vessels (A-D) equipped with AIS were involved in the situation that led to a collision between target "B" and "D". These tracks were produced by using an ECDIS based software on basis of AIS data recorded with own AIS equipment installed in laboratory for scientific investigations and operating in the "listen-mode" only.

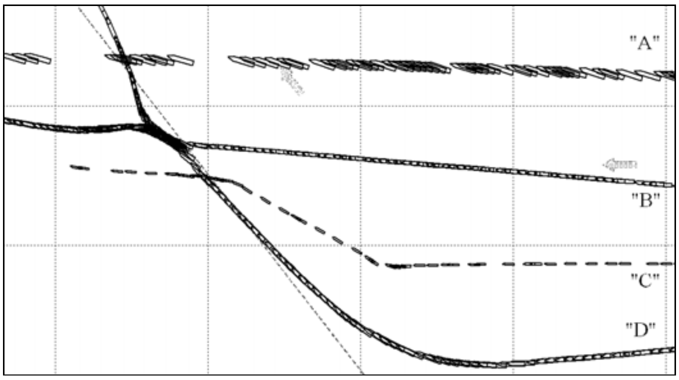

Fig. 4. Target tracks reconstructed on basis of recorded AIS data

For the purposes of a more detailed statistical analysis a section of 20 minutes was taken from the continuous record. The data were modified and made anonymous before the analysis was started. The analysis of the available AIS data was performed with a self created software and numerous results were gained. The intention of the analysis was not to identify who is to blame but to highlight the operation of AIS for further integration of the system into the process.

The main outcome of this analysis can be summarised as follows:
Regarding voyage related data:

- The destination data of at least one of the involved target were not correct, because course data do not correspond with port of destination
- The used format for port of destination and ETA did not comply with the recommendations of the IMO,

Regarding the dynamic data:

- The heading information of one of the involved vessels was obviously wrong (great difference between COG and heading),
- The optional AIS information about rate of turn was not available for major part of the observation period
- Regarding the transmission scheme:
- The standards defined by the responsible organisations require shorter update rates and transmissions if the ship is manoeuvring. Although several course changes were registered from the record, no change in the update rates of the relevant targets was observed during the whole tracking period.
- Furthermore, a number of duplicated and tripled messages, probably from repeater stations, were registered.

On one hand the results of this spotlight confirm the known problems about the reliability respectively the uncertainty of AIS data. On the other hand it also emphasises the necessity of great carefulness when using data of the system for decision making for collision avoidance. The most important issue that is illustrated by the given example is that AIS should never be used as the sole source for decision making.

However, with respect to the potential of integrated navigation systems the example shows also, that there is a urgent need for enhanced alarm management. Obviously no alarm has influenced the situation awareness of the responsible watch officers as intended by the IMO rules. From whatever reason of the officers behaviour that lead to the collision – maybe the dangerous target alarm was not switched on at all - it is to simple, to categorise the cause of the accident as a so called very popular "Human Factor". If that is recognised, then it has at least to be taken into account, that there were more than one "human failure". Regarding the alarming it has to be concluded again, that alarm algorithms has to be much more enhanced. More effective alarms are needed in a way that the only occur in condition, when the operator is really oversee critical conditions and there is a real need to support and complete the officers' situation awareness. This is presently not the case, especially for the dangerous target alarm algorithms implemented to AIS, Radar/ARPA and other integrated systems. That is on reason, way it is allowed to switch of dangerous target alarms.

3 COMBINATION OF INFORMATION

3.1 *Performance Standards on INS*

The existing as well as the reviewed INS performance standards call for combination of systems, data and information '... to provide information giving timely warnings of dangerous situations …'. As already mentioned above, for that purpose, three different priorities indicating three different levels of urgency for taking actions are suggested. This approach may be also useful for the enhancement of dangerous target alarms.

As investigations have shown (inter alia by Baldauf 2006) there is an unsatisfactory exchange of data and information available on a ship's navigational bridge from different sensors and sources. Taking into account the behaviour of navigators it is clear that alarm thresholds for dangerous targets are depending on situation parameters, mainly sea area and visibility but also own ship's and target's speed and course, sizes, manoeuvring characteristics and so on. However, even the simple connection of CPA calculation considering also information on land masses and fairways available from ECDIS are not in use until now. Also the change of manoeuvring characteristics depending on ships speed or loading conditions is not yet covered by any dangerous target alarm implemented to INS.

3.2 *Approach to reduce "Dangerous Target" alarms*

Enhanced alert management of future INS needs more combined use of available information also for triggering dangerous target alarms. For that purpose a first generic concept is drafted to combine target information from different sensors and manoeuvring information that could be triggered by VDR or alternatively also from ECDIS recordings (see Fig. 5).

Core element of the approach is a risk model for situation assessment. It is applied to the IMO's approach of three priority alerts. It is used as a basis for approaching to situation dependent triggering of dangerous target cautions, warnings and alarms as well. By now it is assumed, that cautions and warnings may be switched off by an operator, whereas alarms may not.

The concept of self adaptation of thresholds contains algorithms respectively options to take into account and process sea area and visibility information as well. The manoeuvring information will then be used for automatic adaptation of the TCPA related limits of the dangerous target alarms presently in use.

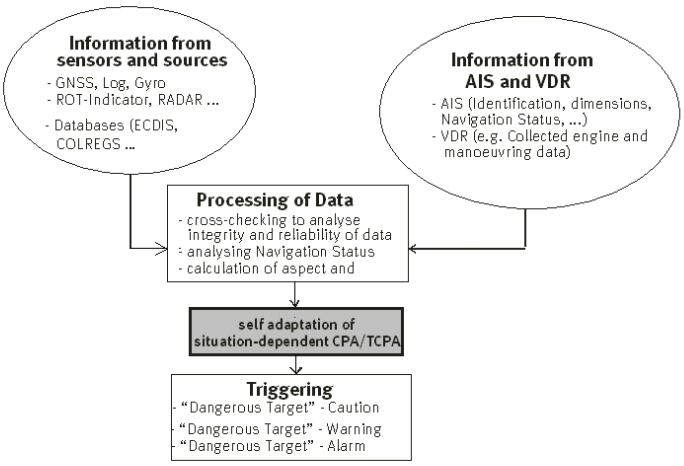

Fig. 5. Generic concept for use of combined information of INS to self-adapting and triggering situation dependent dangerous target alarms

The calculation of the situation dependent thresholds is considering the real ship dimensions and the type of encounter situation as well.

3.3 *Application of a risk model for situation assessment*

Situation assessment is a fundamental basis for actions to avoid collisions. The main problem until today is the lack of missing common parameter and criteria for situation assessment. HILGERT and BALDAUF have already investigated this problem with regard to the need for "on board" assessment of encounter situations taking into consideration the aspect of an existing or developing risk of collision.

The responsible navigational officers have to ensure that the risk level given as an expression of the danger of a collision must be kept on an acceptable level during the entire voyage. Hilgert & Baldauf (1996) has developed of a COLREGS based model consisting of four risk levels. These levels are derived from the actions required by the relevant steering and sailing rules. For the "on board" use of the model variable limit values were defined. They can be calculated and compared with actual measurement values of CPA and the actual distance between ships involved in the encounter situation. An overview on the model is given in following table.

Table 2. Simplified risk model for situation assessment

risk level	limit values and criteria
Level 1: risk of collision is developing	$CPA < C_A$ and $RNG > R_A$
Level 2: risk of collision exists	$CPA < C_A$ and $R_M < RNG \leq R_A$
Level 3: danger of collision is developing	$CPA < C_A$ and $R_C \leq RNG \leq R_M$
Level 4: danger of collisions exists	$CPA < C_H$ and $RNG < R_C$

With respect to the IMO's priorities risk level 2 corresponds to caution (situation requires attention out of ordinary consideration), risk evel 3 corresponds to warning (changed conditions, which may become hazardous, if no actions is taken) and risk level 4 to alarm (immediate action is necessary).

The limit values defined for the model have to be adjusted according to the type of encounter (head – on meeting, overtaking or crossing courses), visibility (good or restricted) and the dimensions of the ships involved. C_A is the limit value for the minimum safe passing distance which must be compared with the actual CPA. Dependent on the specific situation parameters C_A varies between 0,25 nm and 1,5 nm. R_A , R_M and R_C are limit values for distance borders mainly dependent on the relative velocity of the approaching vessels and response time limits for necessary actions to comply with the rules. These values correspond in general to ARPA limits of TCPA.

With respect to an encounter situation on crossing courses under conditions of good visibility the "assessment range" R_A represents that distance from which the "stand on" vessel has to keep her speed and course. If the "give way" vessel has not taken appropriate action up to the "manoeuvring range" R_M, so the "stand on" vessel may take action in accordance with rule 17 (a) (ii). The last limit value represents the "critical range" R_C which indicates that limit for the "stand on" vessel where she has to initiate her evasive manoeuvre according to rule 17 (b) (see following figure).

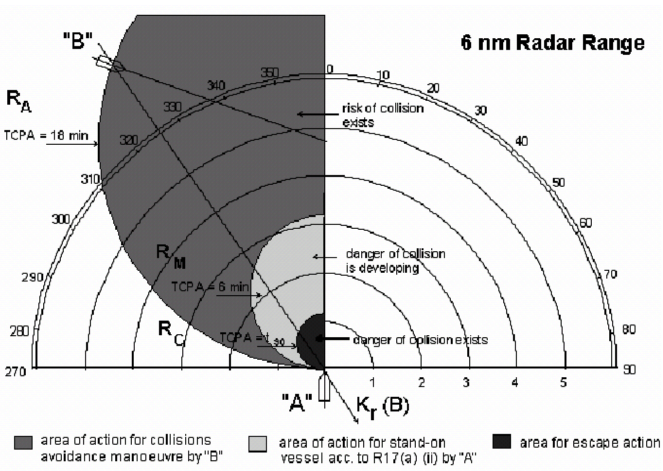

Fig. 6. Application of the risk model to a encounter situation on crossing courses under conditions of good visibility

3.4 *Use of data recorded by VDR or ECDIS*

Recorded manoeuvring data should be used to adapt the limits in a INS according to the prevailing circumstances. Therefore the continuous recordings of integrated systems should be used and relevant data streams extracted to either a manoeuvring database or a simulation module that calculates the necessary manoeuvring parameter on basis of actual measurements. In this way the thresholds for ranges (R_A, R_M, and especially R_C) respectively the corresponding times (especially the time for a course change of 90° as basis of R_C) can be continuously be updated during the voyages of a vessel according to the actual ship and environmental conditions. The principal structure for this application is sketched in the figure below.

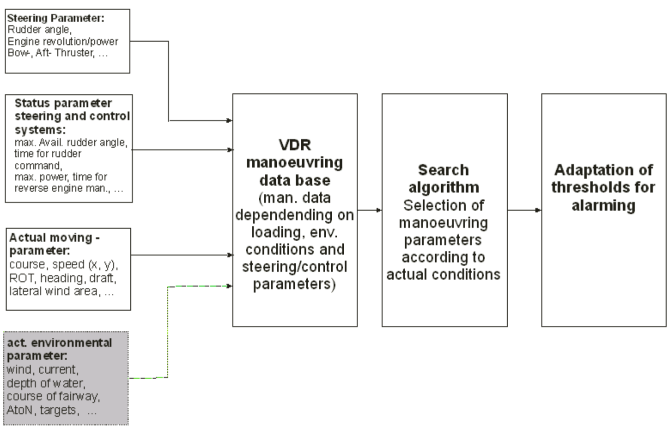

Fig. 7. Principal structure of the application of recorded manoeuvring data for self-adaptation of alarm thresholds

As main source for the database the mandatory installed VDR is preferred. However alternatively ECDIS recording may also be used (Weintrit, 2003).

3.5 *Technical pre-conditions and constraints*

Besides the necessary algorithms that has to be further developed and proved by experimental test trails some technical conditions has also to be arranged before such an enhanced system may be implemented and introduced. First tests using a full mission simulator connected to a full range VDR system has shown, that there is a need for a harmonised data interface that allows for listening and filtering of the recorded data. Presently the technical facilities are of course available to solve this problem but there are some preservations with respect to the IMO Performance standards and other IEC standards, that such interfaces can be used in the frame of a INS also for on-line use.

4 SUMMARY AND OUTLOOK

Investigations into integrated navigation systems and the specific problems of alert management were performed. The present state were analysed in detail by a series of field studies on board several ships. Lacks and shortcomings were identified and dangerous targets alarms were found as a major source for the overall high number of occurring alaerts on a ship's navigational bridge.

An approach to reduce the number of dangerous target alarms is described. The developed concept is based on a risk model for situation assessment and combination especially of AIS and VDR recorded data. It also takes into consideration actual activities of IMO to review the existing Performance standards for integrated navigation systems and an enhanced alert management module.

Next step of the ongoing investigations has to deal with application of the concept and the implementation for experimental trails to especially test the feasibility and acceptance of the approach.

5 ACKNOWLEDGEMNTS

The investigations reported here were part of projects funded by the European Commission, Directorate Energy and Transport and of the German Ministry of Education and Research Berlin.

The authors would like to thank HAPAG-Lloyd and AIDA Cruises Ltd for their grateful assistance and all mariners of the crews who provided their knowledge in interviews on board regarding the alarm management matters.

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