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Abstract: The increasing of a traffic density results in that it becomes too much more difficult for navigator to make the optimum decision for prevention of a dangerous situation. The rapid development of the Communication Technologies and Navigation Aids (Ship’s Radar, AIS, GMDSS, Satellite Navigation, ECDIS, etc.) make it possible to arrange Common Maritime Information Environment for all the ships encountered in Close Quarters situation. The next step should be the automatically exchange of the information between all the ships involved so that all the data for every ship should be available and equal. In these circumstances the equal Shipboard Software for Collision Avoidance installed in all the ships should perform one equal optimum decision on maneuvers. The Results may be used in the developing Shipboard and VTS Software for Collision Avoidance.

Keyword: COLREGS, AIS, GMDSS, satellite navigation, VTS.

1. PROBLEM SPECIFICATION

The problem of safe passing by of vessels in the sea continues to remain rather urgent. The analysis of the reasons of accidents of last period of time shows that the in most cases the human factor lays in a basis of all complex of actions fetching in development of an unfavorable situation at passing by of vessels. It becomes too much more difficult for navigator to make the optimum decision for prevention of a dangerous situation in conditions of intensive traffic. The influence of the human factor may be reduced with the help of technical aids of navigation provided with high-tech computer systems. The rapid development of the Communication Technologies and Navigation Aids (Ship’s Radar, AIS, GMDSS, Satellite Navigation, ECDIS, etc.) make it possible to arrange Common Maritime Information Environment for all the ships encountered in Close Quarters situation.

With all due respect to the incumbent management for collision avoidance COLREGS-72 it must be admitted that the Rules above has been designed for two ships only and could not provide with unambiguous solution in three and more ships encounter. This problem mentioned in E.Naidenov paper:”Whatever the navigator experience be the greater uncertainty in vessels’ encounter evaluation still remains and should remain for ever. In is impossible for human himself to solve the problem of the unambiguous solution of the collision avoidance situation due to the long parameter list. Multivariate of the solutions is still remaining.”[1]. In the reason above the conclusion of the necessity of the “conforming solutions” declared and COLREGS formulization for computer solutions proposed.

Also the necessity of the possible centralization of the maneuver for collision avoidance decision proposed in [2].

The samples of “optimal set of safe trajectories of all ships involved” presented in [3] instead of finding the optimal own trajectory.

There are a lot of samples as above shown that the time is ripe for some modification of the accident prevention in collision avoidance. Everybody seemed agree with that nevertheless a lot of the solutions proposed are too much complicated and uncertain because assumed some “coordinating centers” and “computerized smart technologies” (still not existing).

One more problem is that while making decision on maneuver the navigators (or existing shipboard software) are expecting that all others participants of encounter keep there course and speed.

For example let’s consider the situation of the three ships $A, B, C$ encounter situation in good visibility. We shall use standard radar plotter for graphics performance and standard vector triangle solutions for passing by in distance of 2 n.m.
In figure 2 ship C observed the ship a proceeding from starboard side. According to the rule 15 of COLREGS the ship C is obliged to give a way for the ship A. Using standard graphics solution for this situation the ship C has to change the course to 141° on 12 minute(point 5 in Fig.2) in order to pass by DCPA 2 n.m. from ship A. If however the ships A and B keep their course and speed the collision to be occurred as performed in Fig.2.

This situation from the position of the ship B shown in figure 32 and she also is obliged to give a way for the ship A. Using standard graphics solution for this situation the ship B has to change the course starboard to 86° at 12 minute(point 5 in Fig.3). If however the ships A and C keep their course and speed the collision to be occurred as performed in Fig.3.

If both the maneuvers above will be executed, the close quarters situation between the ships B and C become unavoidable as we can see in Fig.4.

Thus the direct execution of the COLREGS may lead to development of the close quarter’s situation.

And this situation may become worse in condition of restricted visibility. In this case according to the rule 19 of COLREGS no ship has the “right of the way” and the ship A should make a decision to make her own maneuvers.

This situation from the position of the ship A shown in Fig.5. Using standard graphics solution for this situation there are two solutions of course alteration for ship A: to starboard to 041° and to port to 279°. According to rule 19 of COLREGS she should avoid as far as possible the alteration of course to port, but there is no direct prohibition of the alteration of course to port. And providing that the ships B and C should keep their course and speed she may choose alteration of course to port to 279° in reason that in this case she may return to her original course after 19 min instead of 153 min in case of alteration of course to starboard to 041°.
Fig. 5 Vessel B alters course to 086°, C alters course to 141°, A alters course to 279°

Fig. 6 Vessel B alters course to 012°, C keeps course and speed, A alters course to 279°

If all three maneuvers above will be executed, the close quarters situation between the ships A, B, and C become unavoidable as we can see in Fig. 5.

It is just one sample when the third ship in encounter situation should be recognized as the “special circumstances” mentioned in rule 2 of COLREGS and needless to say that a lot of situations like that and even more complicated very often occurred.

Now let’s suppose that the ships A, B, C are working in Common Maritime Information Environment and exchange each other with the information packages through some intervals (say 5 or 10 seconds). The package of information should include position, course and speed, maneuver particulars, restrictions if any. This is already available in modern AIS systems but the speed and volume of data transmission still are not enough for reliable real-time calculations. May be AIS is required to be improved with mobile technology or may be some alternative decision of data exchange – it is obvious that the rapid development of the Communication Technologies should provide this possibility. And we are speaking not of gigabytes, even not megabytes – just kilobytes of data transmission.

And all the ships A, B, C have shipboard computers equipped with the identical collision avoidance software. The calculations of the recommendation on maneuvers start after exchanging of info packages in all the ships simultaneously at synchronized moment of time. The idea is that this collision avoidance program must be able to produce an optimal decision for all the ships involved. In these circumstances the equal Shipboard Software for Collision Avoidance installed in all the ships should perform one equal optimum decision on maneuvers. If the purpose of this program should be to find solution with minimum time of deviation of original course in the sample above we should obtain the recommendations as follows:

- ship A alters course to port up to 279° and return to her original course after 12 min;
- ship B alters course to port up to 012° and return to her original course after 18 min;
- ship C keeps her course and speed;

If these two maneuvers above will be executed, all the ships proceed safely with DCPA 2n.m. as we can see in figure 6 from the view of ship C.

The solution performed seemed not to comply exactly with the COLREGS (in good visibility the ship A should keep her course and speed according to rule 17 of COLREGS and in poor visibility she should avoid as far as possible the alteration of course to port ). But we must admit that that the COLREGS has been developed for two ships only and can not provide us with the unequivocal decision if there are three and more ships in encounter.
2. PROGRAM (PATENT) FOR SOLUTION

*Fig.7a* Randomly generated situation of 9 vessels encounter (screenshot)

The screenshots of the “Program of the unfavorable close quarters situation with the safety vessels’ pass by maneuvers calculation follows” registrated at the Federal Intellectual Property Service performed in *Fig.7a,b.*

Randomly generated situation of 9 vessels encounter performed in *Fig.7a* with some dangerous close quarters.

Maneuvers for collision avoidance demonstrated in *Fig.7b.* Recommendations for collision avoidance performed in a table.

*Fig.7b* Sample of the coordinated maneuvers for collision avoidance with 9 vessels (screenshot)

The patent of invention “Collision Avoidance System using Common Maritime Information Environment” has been registrated at the Federal Intellectual Property Service. The concept of operation schematically presented in *Fig.8:*

The data from the input peripherals encapsulated the ships’ information. These packages periodically transmitted through the VHF aerial frequency interval 1a. The similar packages from the other ships located in VHF
range are received simultaneously. The received information is automatically adapted and displayed in operation desk. The radio synchronization between all the AIS maintained by Global Navigation Satellite System (GNSS).

The position and velocity are calculated with the GNSS signals. The received information from AIS block 1 is transmitted in the AIS block 2 where is compared with the similar data received from the Radar and ARPA of the own ship. If the information confirmed the signal of the confirmation and the time of the readiness to start the maneuver if required to be transmitted on all the other ships involved. If the data of position, velocity and course differ in appraisal with the data from another ship than automatically start the process of data exchange for coordination and after approval these two ships transmit the signal of the confirmation and the time of the readiness to start the maneuver on all the other ships involved. When all the confirmations to be received the coordinated package transmitted to the on-board computer 3 to calculate the optimal solution for maneuvers for all the ships to the time point highest from all confirmed. And every computer in every ship performed the same solution.

The main advantage of the technology proposed is that human factor to be excluded from the data exchange between vessels. There are a lot of samples when the navigators tried to “improve” the COLREGS with VHF and thus emergency situation created. The reasons well known: misunderstanding, language problems and identification mistakes. The automatically data exchange provides the reliable information double-checked and synchronized for a split second.

The real-time program every time of the data exchange should correct the actions due to possible deviation from the scenario supposed.

In the samples above the safety criterion based on the distance of the closest point of approach (DCPA) just for facilitating of the understanding of the method. The advanced solutions may be based on “ship’s domain” [1] or on DCPA base on the most unfavorable maneuver [4]. The possibility of the speed maneuver also to be considered especially in the limited harbor areas, and software for safety passing by with allocation of speed only already exists [5].

Therefore from technical side of the problem everything is available for solution: the rapid and reliable data exchange between the participants of the encounter should be developed in nearest future, the software for collision avoidance in real time also should be developed in short time. And no need especial computer hardware for Shipboard Software for Collision Avoidance: usual modern comp is enough, only interface problem computer to connect with navigation and communication aids – also not too as much technical problem.

CONCLUSIONS.

The main problem is organization and reliability of work of the equipment. The “organization” means that the all of ships should be equipped with compatible navigation and communication aids. First step has been done: AIS according to the Resolution IMO MSC.74 (69) of May 12, 1998 are already in use for quite a long time, and there is quite enough experience in AIS application. Using the experience above the next generation of AIS should be improved with mobile technology or may be some alternative decision of data exchange in the scope of Europe’s 2020 strategy of Common Information Sharing Environment(CISE) development which included “Monitoring of compliance with regulations on the safety of navigation(vessel traffic safety)”. The reliability of work of the equipment may be achieved by using duplicating and/or reserved schemes.

Needless to say that the implementation of the technology proposed should demand the decision of set of legal questions connecting with responsibility of every participant of encounter process and the COLREGS in current condition may be not able to give the answers on all questions.

The road map time line of the system proposed implementation as follows:
1. The additional AIS block for connection with Radar and ARPA designing.
2. Coordinated data package and protocol of the data exchange designing.
3. Software for the on-board computers designing.
4. Series of the global experiments using the net of navigation simulators preparation and realization.

After virtual experiments and discussion the technology proposed may be implemented to the acting fleet. With the forthcoming Long Range Identification and Tracking System and the system invented the close quarters situations should be excluded before the ships insight.

REFERENCES