ALGORITHM OF SHIP-TRAFFIC CONTROL ON THE LIMITED HARBOR AREA BASED ON ALLOCATION OF VESSELS SPEED

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The increasing of a traffic density results in that it becomes more difficult to the VTS operators to accept the optimum decision. An algorithm of ship-traffic control in the limited harbor area only by allocation of the speed of the vessels is presented in the article with explanations and illustrations. Results may be used for the working and in the developing of ARPA and VTS.

Keywords: vessel speed allocation, ship traffic control, ARPA, VTS, harbor area.

The analysis of the reasons of accidents during last period shows that in most cases the human factor lays in a basis of all complexes of actions fetching in development of an unfavorable situation at passing by of vessels.

The effect of the human factor on safety of passing by vessels within the limited harbor area can be essentially reduced with the assistance of the high-tech computers analyzing the development of ships encounter situation on basis of the objective criteria of passing by safety. The development of the appropriate mathematical and software solutions will allow avoiding occasions when the situation of approaching vessels can be considered as dangerous and also minimizing losses of operational time due to collision avoidance maneuvers.

The basic requirements for the algorithm of ship-traffic control on the limited harbor area are as follows:

1. The vessels should proceed so that at any moment of time in case of any unfavorable maneuver of one or both vessels leading to near collision, even one of them has had enough time to notice development of a dangerous situation and to realize actions for collision avoidance;
2. The actions recommended by the algorithm should be as close to actions appropriate to COLREGS-72 as possible;
3. Every vessel should reach the point of destination as quickly as it is possible without breaking the first two principles;
4. The algorithm of management should provide an opportunity of addition and thickening of soluble tasks.

An algorithm of a ship-traffic control on the limited harbor area only by allocation of the speed of the vessels has been designed and realized in Maritime State University (Vladivostok).

The coefficients of the equations of movement of a vessel at collision avoidance maneuvers only by allocation of the speed were selected for the data of full-scale tests of vessels on a minimum of summarized quadratic deflection of predicted data from experimental.

The offered model is not essentially important for developed algorithm of management. The advantage that for construction of a mathematical model of maneuvering is enough of the minimal information on a vessel: a length of a vessel overall and velocity of full ahead.

In a VTS area for each of considered vessels the presence of the following information is supposed:

- length overall;
- maximal velocity of full ahead;
- condition of a vessel (in a cargo or in ballast).

Every ship assumed to proceed with fixed predetermined route regarding traffic lanes restrictions and navigational obstacles. To the moment of a beginning of calculation of the advisories on maneuvering the presence of the following information for each vessel is supposed:

- position of a vessel;
- a ship's engine order telegraph position;
- current velocity.

These data are made in the computer as results of processing observations of radar stations and communication between participants of movement.

The program designed works as follows:

1. the sequence of dangerous pares is selectable from all the pares at which distance of the closest point of approach less then allowable;
2. the pare with the minimal time of the closest approach is selectable from all these dangerous pares;
3. with the help of a recursive subprogram described below a collision avoidance maneuver and time of return to former velocity for one of vessels of the considered pare produced;
4. return to item 1 of the program; now the pare, for which the advisories on movement were produced, any more will not be dangerous, and is selectable the following dangerous pair, and so long as at the all pares the distance of the close point of approach becomes more then allowable.

Certainly there are some other possible solutions in a choice of the advisories on maneuvering concerned. However algorithm of the program is polynomial, the time of the decision is proportional to a square of quantity of considered vessels. Therefore algorithm is quite applicable for practice of a ship-traffic control on the limited harbor area. The advisories on maneuvering for pare of vessels are made with the help of a recursive subprogram. On an input of a subprogram are assumed given:

- the characteristics of vessels in given pare (coordinate, velocities, sizes, maneuverable elements, expected route, etc.);
- the advisories on maneuvering for each vessel in given pare produced to the current moment of calculations.

The recursive subprogram works as follows:

1. If for one vessel in given pare to the current moment of calculations were not produced the advisories on maneuvering in other pares,

or they were produced for both vessels, is sorted out at first stopping maneuvers for a vessel obliged in this a pare to give the way;

2. If only for one vessel of the pare to the current moment of calculations are produced the advisories on maneuvering, we sort out stopping maneuvers for this vessel;
3. If the stopping maneuver ensure safe proceeding the moment of time when it is possible for maneuvering vessel of return to former velocity is calculated;

Alternatively: we leave in force for a considered vessel the same advisories as at the beginning on an entrance in a subprogram, and we sort out stopping maneuvers and time of return to former velocity of other vessel.

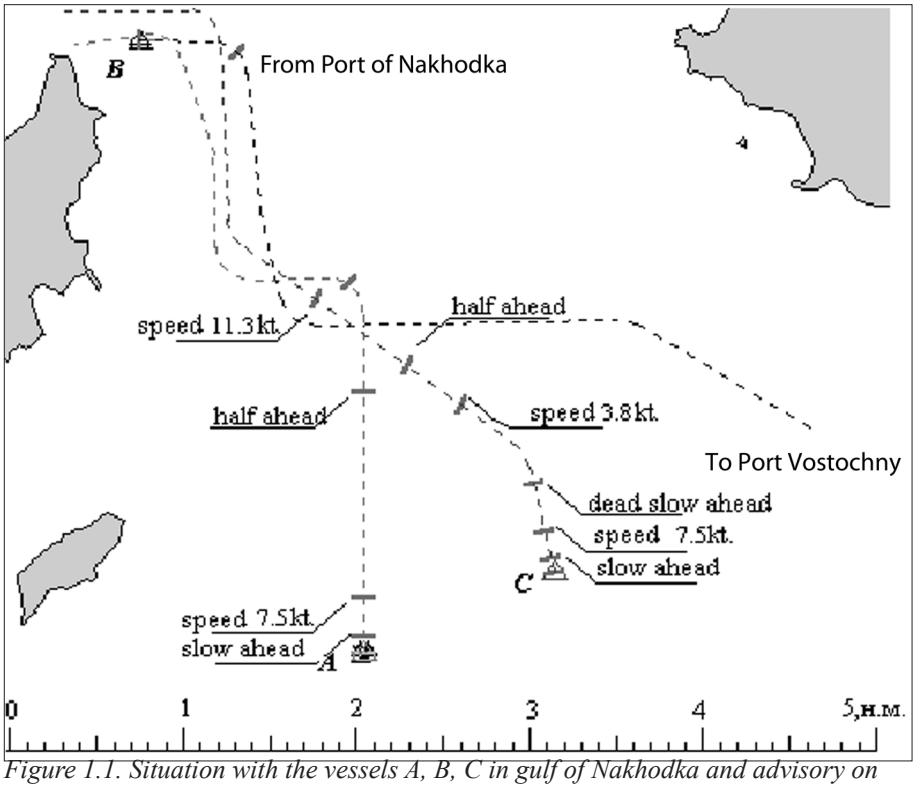

Figure 1.1. Situation with the vessels A, B, C in gulf of Nakhodka and advisory on maneuvering

Let's consider an example of realization of the program in a fig. 1.1:
ALPHA - is heaved up anchor and with half ahead speed 11.3 kt. proceeds to the port of Nakhodka;
BRAVO - near port of Nakhodka increases speed up to half ahead 13.5 kt. and proceeds to the port of Vostochny;
CHARLY - is heaved up anchor and with half-ahead speed 11.0 kt. proceeds to the port of Nakhodka;
The program analyzes relative positions and moving of vessels and gives out the following advisories:

Operative time	a vessel	telegraph position
00:01:26	ALPHA	slow ahead
00:01:30	CHARLY	slow ahead
00:04:39	CHARLY	dead slow ahead
00:18:49	CHARLY	half ahead
00:12:23	ALPHA	half ahead

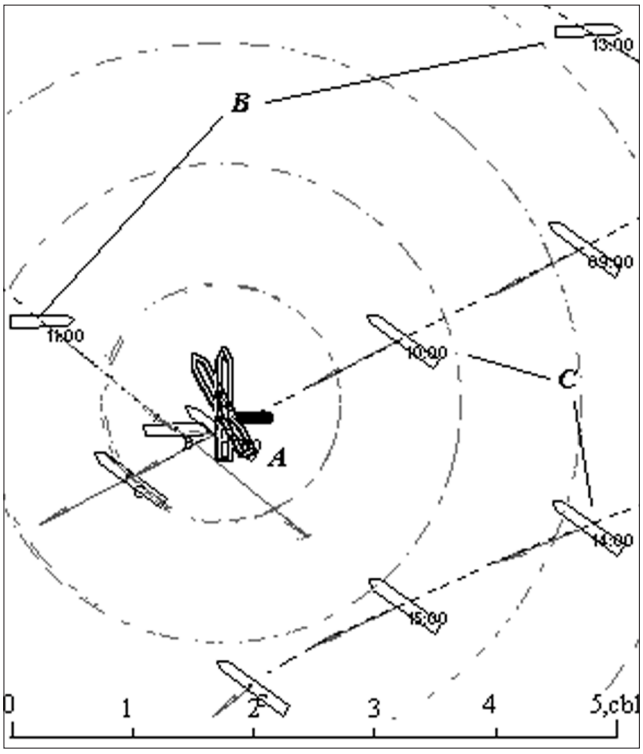

Figure 1.2. Superimposition of relative traces of vessels B, C relatively to vessel A while proceeding according to the advisories and in a case if no appropriate actions to be performed.

On the Figure 1.2 the situations of relative motion are given while proceeding according to the advisories and in a case if no appropriate actions to be performed from a position of a vessel A in north oriented datum.

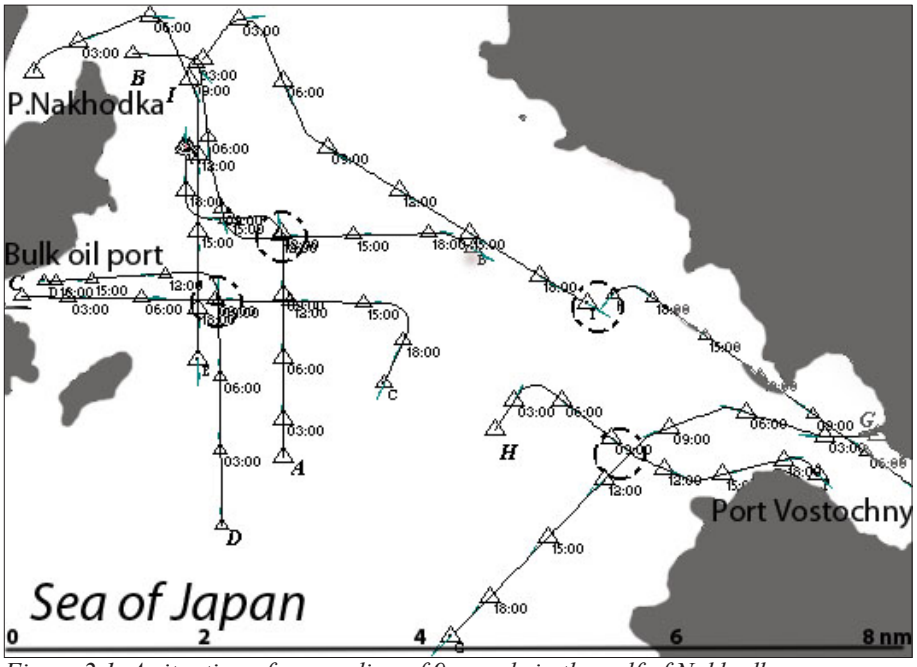

Figure 2.1. A situation of proceeding of 9 vessels in the gulf of Nakhodka.

ALPHA - has heaved up an anchor and with half ahead speed 11.3 kt. proceeds to the port of Nakhodka;

BRAVO - near port of Nakhodka increases speed up to half ahead 13.5 kt. and proceeds to the port of Vostochny;

CHARLIE - leaves from a bulk-oil port and with half ahead speed 13.5kt. proceeds to the anchorage;

DELTA - follows from the open sea to the bulk-oil port with half ahead speed 13.5 kt.;

ECHO - proceeds from the port of Nakhodka to the open sea with a full speed 14.0 kt.;

FOXTROT - has heaved up an anchor and with half ahead speed 11.3kt. proceeds to the port of Vostochny;

GOLF - proceeds from the port of Vostochny to the open sea with a full speed 15.0 kt.;

HOTEL - proceeds from the port of Vostochny and with half ahead speed 12.0kt. proceeds to the anchorage;

INDIA - has heaved up an anchor and with half ahead 11.3 kt. and proceeds to the port of Vostochny;

The following pares of vessels dangerously approach, if not it will be accepted of the appropriate actions:

CHARLIE and DELTA	through	00:09:00;
FOXTROT and GOLF	through	00:10:30;
ALPHA and BRAVO	through	00:12:00;
HOTEL and INDIA	through	00:20:30.

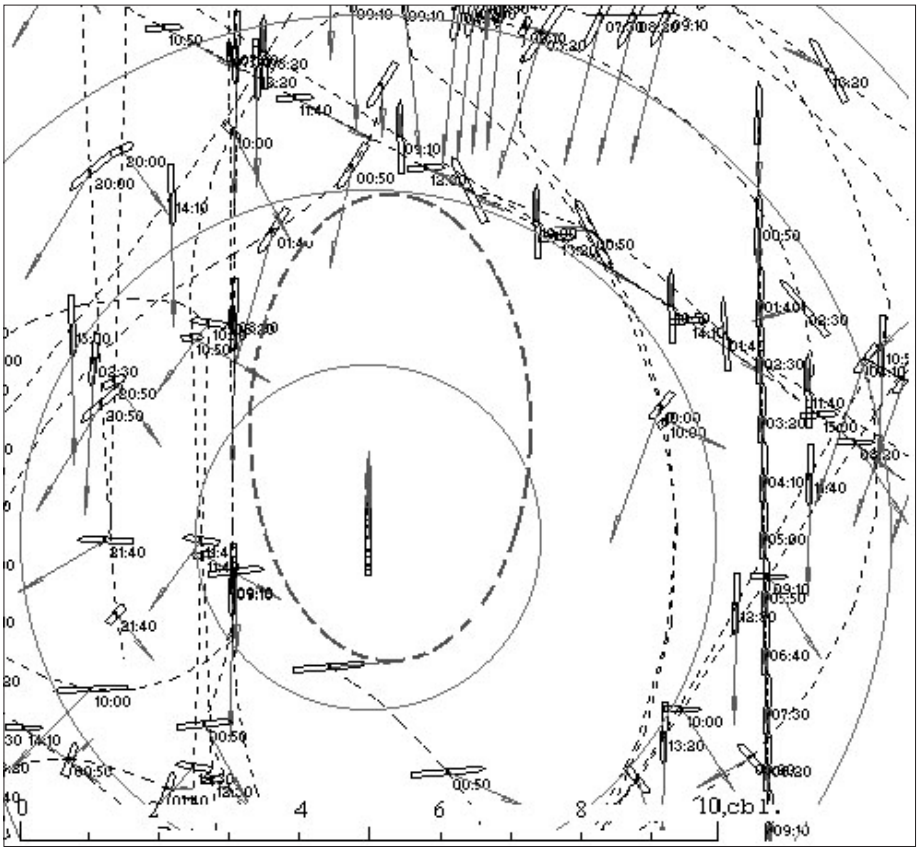

Figure 2.2. Superimposition of the relative traces of the all 9 vessels in course oriented datum

The program analyzes relative positions and moving of vessels and gives out the following advisories:

Operative time	m/v	telegraph position
00:01:26	ALPHA	slow ahead
00:01:47	CHARLIE	slow ahead
00:02:15	FOXTROT	dead slow ahead

Operative time	m/v	telegraph position
00:09:19	HOTEL	half ahead
00:11:54	CHARLIE	half ahead
00:12:30	ALPHA	half ahead
00:16:03	FOXTROT	half ahead
00:21:28	HOTEL	full ahead

In a Figure 2.2 the superimposition of the relative traces of the all 9 vessels in course oriented datum performed. Each of the considered vessels has been positioned at the centre of the drawing.

The safety area free from other vessels and entities is distinctly visible around of a vessel in centre of the figure 2.2. The form and the sizes of this area are quite similar to the sizes to a safety area (ship's domain) received as a result of superimposition of lines of relative y movement obtained from the vessels in real conditions of sailing and on radar simulators. Also it is distinctly visible that the vessels from the starboard side meet much less often than from the port. It means that while performance of the advisories the vessels will more often pass by port sides, and that also corresponds to usual maritime practice.

The situations of rapprochement of the vessels similar above were considered in every possible combinations at variation of input data. In all cases the similar results were received.

Of course it is impossible to write such program of regulation of movement of crossed traffic flows, which could at once be applied to any VTS area. Every VTS area has the specificity determined by a set of conditions: the requirements to a position fixing accuracy of a vessel and parameters of movement, presence of navigational hazards, organization of communication between a control centre and vessels in VTS area, etc. All these conditions should be adopted in a complex at realization of algorithm of management with reference to the actual VTS.

According to the SOLAS Convention Automatic Identification System (AIS) now start to develop and the appropriate aids of navigation is subject to installation on the majority of types of vessels since July 1, 2002. Assignment and the basic functions AIS are officially defined in the Resolution IMO MSC.74 (69) of May 12, 1998.

The above is a necessary base for introduction of the programs of a ship-traffic control on the limited harbor area. The following logical step in the further development of the navigation aids is an expansion of the functions VTS up to automated recommendations on maneuvering for all the vessels in an operative range of the VTS.

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