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SITUATIONAL METHOD OF NAVIGATIONAL SAFETY ASSESSMENT

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In process of navigation navigational safety is a matter of upmost importance. Navigation is a process of realization of complicated goal driven organizational and technical system of shipping. This system functions in an environment consisting of various chaotic factors arising from navigational hydrographic and hydrometeorological conditions as well as vessel's own condition and maneuverability and navigator's skills to make a full appraisal of the situation in the prevailing circumstances and conditions. [1]

Actual control over a vessel consists of appraisal of situation, making decisions to maneuver and conducting ~~the~~ maneuver. Any element in this chain of actions may be the cause of some error which can respectively cause additional impact on a risk of navigational hazard.

Various aspects give reason to not consider navigational hazard as a probability which may occur when approaching another vessel at range less than preassigned but as an expected value of dangerous navigational situations. Knowing rate of transition from dangerous navigational situations to averages and collisions, it's possible to analytically predict casualties, ecological and economical losses caused by occurred hazards.

Mathematical model of organizational and technical system of navigation is made in respect to modern methods of algebraically formal systems which include methods of functional-structural human-machine systems, I-nets, semi-Markov chains, semantic chains, etc. [2]

Sequence of occurring events is similar for all these methods, it's represented by arcs of oriented graphs. Starting and ending events of a specific event are represented by peaks. The main unit of measurement in this system is probability for the event to occur.

It will be common sense to include situations which are most likely to happen in our logical data model of navigation: a single vessel going on a voyage in complex navigational environment, and situations when two vessels pass each other in complex navigational environment, when collision is possible, as well as encountering navigational hazards, which may lead to at least one of said vessels to run aground. Then, all events considered in mathematical model of navigation will have disjunctive connection with separated events.

Logical data model characterizing connections between main events in navigation is given in Fig 1.

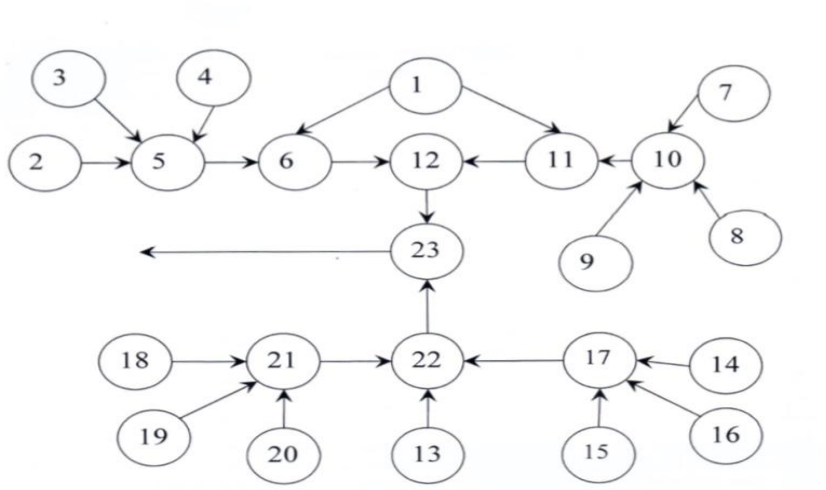

Fig. 1. Logical data model of dangerous navigation situation

In this model following dangerous navigational events to happen in constrained navigational environment included:

1. Event P_1 characterizing good navigational circumstances in sailing area.

2. Event P_2 characterizing correct appraisal of prevailing situating on single vessel.
3. Event P_3 of making correct decision to maneuver on single vessel.
4. Event P_4 characterizing correct performance of maneuver by single vessel.
5. Event P_6 characterizing navigational hazard appearance e.g. running aground.
6. Event P_7, P_8, P_9 similar to events P_2, P_3, P_4 but for other vessel; P_5, P_{10} – additional events.
7. Event P_{13} – event characterizing good above-water circumstances.
8. Events $P_{14}, P_{15}, P_{16}, P_{17}, P_{18}, P_{19}, P_{20}, P_{21}$ – events characterizing correct appraisal of above-water circumstances, decision making and maneuver performance on both vessels passing each other.
9. Event P_{22} – event characterizing vessels approaching at distances closer than assigned.
10. Event P_{23} – event characterizing appearance of dangerous navigational hazard caused by vessels' approaching each other at close distances or running aground during passing in complicated navigational circumstances.

Main events are linked with each other by disjunctive connections that highlight tasks of determining the highest probability of possible navigational hazards during navigation in complex circumstances.

To find probabilities for complex situation to happen disjunctive normal function [3] should be found. Logical operations of disjunction, conjunction and inversion should be exchanged with their probabilistic equivalents as follows:

$$\begin{aligned} a = a_1 a_2 &\rightarrow P_{a_1} P_{a_2} \\ b = a_1 \cup a_2 &\rightarrow P_{a_1} + P_{a_2} - P_{a_1} P_{a_2} \\ c = f_1 &\rightarrow P_z = 1 - P_{a_1} \end{aligned} \quad (1)$$

General expression of probability for dangerous navigational situations to occur when navigating in complex circumstances looks like:

$$P_{OHC} = (1 - P_1)P_6 + P_1(1 - P_4)P_5P_6 + P_1(1 - P_3)P_4P_5P_6 + P_1(1 - P_2)P_3P_4P_5P_6 \quad (2)$$

Where $P_1 - P_6$ – probabilities for respective events included in logical model of navigation in complex circumstances to occur.

This method of assessment gives us opportunity to assess risks to navigation as well as operator's skills. Results of our assessment show how even tiniest changes in probabilities lead to drastic increase in hazard occurrences, as well as the importance of proper lookout from navigator, probability of which should be not lower than 0.95. This model may be improved by further research and investigations which would help to input more accurate probabilities true to the actual environments and adjust position of events in our model.

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