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Automation of processes of identifying navigation situations requiring communication to be established by a sea-going vessel

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Abstract
One of the causes of ships' accidents are errors in the communication between navigators in charge of ships concerned. The most common causes include a lack of communication, misunderstanding of a received message, incorrect choice of the type of message or misinterpretation of the information exchanged. These errors can be significantly reduced by the automation of intership communication processes, in particular by a developed automatic maritime communication system. The decision to communicate is as essential as communication itself. This paper presents the problem of identifying situations requiring the establishing of communication by a sea-going vessel. A definition of the need to establish communication between the vessels is associated with the acquisition of data, analysis and evaluation of the navigational situation and the relevant inference process. Based on an analysis of the process of identifying navigation situations which require communication between proceeding ships, the model of automatic identification of such situations has been developed.

Introduction

Access to required up-to-date and reliable information is of primary importance for correct navigational decision making on ships and at land-based centres alike. Developed to this end by the IMO is the concept of e-navigation, based on an increasingly standardized form of navigational information and the standardization and automation of information exchange.

A complex character of a navigational situation may call for establishing communication between navigators steering their ships in vicinity of each other or between navigators and land-based centre personnel [1]. This refers to the need of ascertaining the actual situation, intentions of the ships involved or agreeing on manoeuvres to be performed. Hence we should expect that the next step will be taken towards the automation of communication processes taking place between navigators on board and land-based centre operators. Rapid advancements in IT and ICT technologies open possibilities for automated communications between shipboard and shore IT systems, and, in various combinations and proportions, between operators and IT systems. This will allow to restrict possibilities of human errors, such as failure to establish communication, misunderstanding of a received message, improper choice of a message or wrong interpretation of exchanged information. Such reduction will contribute to the enhancement of navigational safety.

The identification of the need of establishing communication between ships or between a ship and a land-based centre involves the acquisition of data, an analysis and assessment of a navigational situation and conducting the process of inference in this area.

Automation of communication processes in marine navigation

Communication processes in marine navigation

Participants of communication processes in maritime shipping are ship navigators, land-based personnel of VTS and similar centres, shipowners, forwarders and others. The principles of communication between them are provided in relevant regulations, defining obligations resting on traffic participants. However, regulations do not eliminate possibilities of dangerous situations that may result, among others, from a failure to start communication or misunderstandings.

Correct and effective communication is of particular significance in situations threatening the safety of people, means of transport (ship), cargo or/and environment. Therefore, it seems purposeful, in defining areas of communication, to adopt the classification commonly used in the GMDSS system (Global Maritime Distress and Safety System) [2, 3] with strict rules and procedures for priority communications:

– distress communication (collisions, rescue of life and property);
– urgency communication (e.g. medical advice or assistance);
– safety communication (e.g. navigational and meteorological warnings).

Another mode in the GMDSS system is the so called routine communication. It is used, for instance, in situations where ships report their presence in traffic separation schemes or reporting systems. Routine messages, unlike the priority communication, do not have in the GMDSS a strictly defined procedure or circumstances that would make communication obligatory or recommended. This is due to a lack of legal measures that would regulate routine communication. The four aforesaid modes of communication (distress, urgency, safety and routine) define thematic areas of messages sent by participants of the transport process in marine shipping.

Communication processes in general comprise the transmission of information between a sender and a receiver. Taking into account the scope of conducted communications various aspects [3]:

– acquisition, processing, transmission and presentation of information, using standard navigational equipment and systems;
– selective acquisition of information (information needed in a given situation) for identification or more accurate description, interpretation, assessment of a present and/or predicted situation, intentions of traffic participants;
– mechanisms of co-operation and negotiations concerning safe ship conduct, avoidance of threats and the prevention and minimizing consequences of accidents.

Navigational information is nowadays acquired, integrated, processed, transmitted and presented to an increasingly wider extent. This is possible thanks to introduced standards of content and form of navigational information.

However, both navigators and shore operators of vessel traffic find it often necessary to obtain specific, i.e. selected information. This particularly refers to the acquisition of supplementary information and necessitates the establishment of communication for supplementing specific data through a dialog. This can be an oral exchange performed via a VHF radiotelephone.

Tasks of an automatic communication system in marine navigation

Tasks to be performed by the proposed system of automatic communication in marine navigation [4] correspond to the areas and ranges of communication processes taking place in maritime transport (see section *Communication processes in marine navigatio*). In a nutshell, they refer to:

1) acquisition and presentation of information,
2) mechanisms of communication and negotiations between ships and land-based centres.

The automation of communication in marine navigation at present refers to a typical exchange of data obtained from shipboard and shore navigational equipment and systems and addresses the former communication task area. Actually, the ongoing standardization of navigational or operational data scope and format goes in line and facilitates such automation. It seems particularly vital to broaden automatic communication to include selective acquisition of data needed in a given situation for identification or more accurate description, interpretation, assessment of a present and/or predicted situation, intentions of traffic participants.

Equally important in the system of automatic communication in marine navigation is the development and implementation of co-operation and negotiations mechanisms referring to safe conduct of the ship, avoidance of threats and the prevention and minimizing effects of accidents.

The mentioned mechanisms of selective information acquisition and mechanisms of co-operation and negotiations should take into account various forms of communication, resulting from the needs of users and from the transformation of communication processes:

- person – person, via a computer system (manual mode);
- person – computer system (in both directions, any range) (semi-automatic mode);
- computer system – computer system (automatic system).

The automation of both selective information acquisition and negotiation processes require the knowledge of inference rules for an analysis and interpretation of dialog contents. The rules refer to the identification of navigational situations requiring communication to be established by a ship or land-based centre, as well as the very mechanisms of communication and negotiations (form, area, range and time constraints / requirements).

Automatic execution of communication should also take into consideration the specific manner of verbal exchange by people. It should reflect and relevantly employ linguistic variables and values that people use.

For the automatic communication process to run correctly, the need for its initiation or continuation by an operator or system has to be first identified. This refers to both periodic stimuli (events at known time of occurrence) and non-periodic stimuli (events whose moment of occurrence is not known in advance).

Process of identifying navigational situations requiring communication to be established by a sea-going vessel

Priority communications

In an analysis of issues referring to the needs of communication for predefined areas of communication we examined navigational situations including cases of collision threats, and specific distress, safety and urgency message exchanges.

Collisions

Parameters that unequivocally indicate a risk of collision or close quarters situation are the Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA). To calculate these parameters we have to know the positions and movement parameters of own and target ships (latitude and longitude, or possibly X/Y, course over the water and speed through water). Besides, when qualifying an encounter situation according to the Collision Regulations, we have to know true courses and navigational status of both ships. To determine whether a target ship is manoeuvring, its rate of turn has to be known, while the ship can be identified by its MMSI, call sign or name.

Limit (acceptable) values of CPA and TCPA, denoted as CPA_L and $TCPA_L$ – are specified for a given ship by its navigator (mostly instructed by the captain). The respective values in the open sea area are usually 1 Nm and 15 minutes. In a restricted area, the time is usually reduced to 10 minutes. The CPA value depends on ship size. The problem of determining CPA_L and $TCPA_L$ was examined in a number of real field, simulation and questionnair-based tests [5, 6].

Here is an example of a message sent in a collision risk situation from ship A to ship B:

A to B: ship B, CPA is 0 Nm, TCPA is 15 minute, you are a give-way vessel (Rule 15 – crossing courses), alter your course to starboard to pass astern of me.

The transmission of such message is preceded by an analysis of the relevant navigational situation and ascertaining the need for communication. This process is defined as identification of a navigational situation that necessitates establishment of communication by a vessel. The communication can be executed semi-automatically, using a message form filled out by the navigator, or automatically, where both the communication need identification and message preparation and sending are performed by a system of automatic communication.

Distress, urgency and safety communications

It seems that this type of communications should be executed semi-automatically, based on ready-made forms filled out by the navigator. On this basis, the system would generate an appropriate message. This actually means that the system does not establish communication with another ship or a centre automatically. Here is an example distress, urgency or safety communication where a form filled out by a navigator is used:

1. Priority: distress / urgency / safety;
2. In case of distress – type of danger: collision, abandon ship, grounding, fire, pirates etc.;
3. Ship position and time when obtained (acquired automatically);
4. Number of personnel, number of injured persons;
5. Required assistance;
6. Other information useful in rescue operation.

After the form is filled out, the system generates a message (it may also be a voice message), for instance this one:

MAYDAY
THIS IS vessel A
I am sinking in psn …………… at …..UTC
20 persons on board, 2 badly injured
Required immediate assistance
Rough sea, wind NW 10B
OVER

Routine communications

Some navigational situations requiring routine communication have also been considered. They comprised navigation in areas where reporting systems and pilot navigation are in use.

VTS (reporting systems)

The reporting procedure is one of standard routine procedures performed by ships entering areas supervised by VTS centres. An example communication exchange between of ship A and a land-based centre can run like this:

A to VTS: VTS, this is ship A, I have crossed eastern boundary of the reporting system, my position is ….., course and speed ….. Over.
VTS to A: ship A, this is VTS, what was your last port of call, what is your destination? Over.
A to VTS: VTS, this is ship A, I am proceeding from ………… to ………. Over.
VTS to A: ship A, this is VTS, are you carrying dangerous goods? Over.
A to VTS: VTS, this is ship A: Yes, dangerous goods class 1.4, 2, 3, 5, 8 and 9. Total weight 865 123 kg. Over.
VTS to A: ship A, this is VTS, thank you for the report, keep continuous watch on Channel .... during the passage. Out.

The amount of data and VTS enquiries may vary depending on a specific VTS centre, so that questions may refer to the port of departure, class and quantities of dangerous goods, number of crew members, number of passengers etc.

Communications of this type may be conducted in a semi-automatic mode, based on existing forms the navigator has to fill out, in a fully automatic mode.

The problem of communication need identification requires that a relevant VTS centre be identified, as it has its specific requirements for report form, scope and time of establishing communication.

VTS (pilotage)

Another procedure in routine communication is pilot boarding procedure. Here is an example communication between ship A and a VTS centre VTS:

A to VTS: VTS, this is ship A, I will be at pilot station in two hours, over.
VTS to A: ship A, this is VTS, what was your last port of call? What is your draft forward and aft? Over.
A to VTS: VTS, this is ship A, I am proceeding from Casablanca. My draft forward is 6 m, my draft aft is 6.2 m. Over.
VTS to A: ship A, this is VTS, are you carrying dangerous goods? Over.
A to VTS: VTS, this is ship A: Yes, class 1.4, 2, 3, 5, 8 and 9. Total weight is 865 123 kg. Over....

Further course of communication and scope of data required by a VTS operator depends on principles and regulations observed within a given area and its port/s (name of the agency, captain's name, last ten ports of call and days of departures etc.). The communication usually ends like this:

VTS to A: ship A, this is VTS, thank you for your report, pilot will be waiting for you on pilot station at ………….., rig a pilot ladder on ..... side, …….. metres above water, keep continuous watch on Channel …

A model of automatic identification of navigational situations requiring communication to be established by a sea-going vessel

Algorithmization of the navigational situation identification

In the previous chapter we presented examples of identification of navigational situations for various events. As a step towards the automation of identification, it can be presented in a form of a checklist, whose fragment is given below:

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1. Was there an external calling?
2. If NO: Go to DISTRESS COMMUNICATION.
3. Send a control to the reception module and message analysis
DISTRESS COMMUNICATION:
4. Is distress / urgency / safety communication required? (navigator's decision)
5. If NO: Go to RISK OF COLLISION
6. Select a proper message format (navigator's decision)
7. Fill out the form with information from shipboard systems
8. Fill out the form with information from external systems (done by the navigator)
9. Go to COMMUNICATION
RISK OF COLLISION:
10. Is there a risk of collision (based on CPA, TCPA and limit CPA and TCPA set by the navigator)?
11. If NO: Go to VTS
12. Am I a give-way vessel (due to reduced visibility or according to regulations)?
13. If NO: Go to COMMUNICATION
14. Inform the navigator on the obligation to give way
VTS:
15. Is the ship approaching the boundary of the reporting system or has it crossed the limit?
16. If NO: Go to END
17. Has a report been sent?
18. If YES: Go to PILOTAGE
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19. Read out the list of information
    to be reported to VTS from the
    data base
20. Retrieve required information from
    shipboard systems, if not avail-
    able, from the navigator
21. Go to COMMUNICATION
PILOTAGE:
22. Is pilot necessary in further ma-
    noeuvres?
23. If NO: Go to END
24. Is the time to reach the pilot
    station within limits set by the
    navigator?
25. If NO: Go to END
26. Read out from the data base a list
    of information items required by
    the VTS and pilot station
27. Retrieve required information from
    shipboard systems, if not avail-
    able, from the navigator
COMMUNICATION:
28. Prepare information on the naviga-
    tional situation and method of
    communication, then send a control
    to the communication system which
    will prepare and send a proper
    message
END:
29. No need to establish communication
30. Stop
```

The above algorithm should be regarded as a general form, a basis for creating an algorithm of the identification of a navigational situation involving own ship that will require communication to be established.

A generalized algorithm for the identification of communication need

If individual situations for which a decision to establish communication has to be made are independent, then appropriate rules can be developed for these situations. The process of automatic identification of a navigational situation requiring communication will be a sequence of launches of these rules for predetermined premises and checks of the conclusions resulting from them.

We resolved on considering situations separately for each of the objects (ships, land-based centres), as presented in figure 1. If there is a rule for which the premises are fulfilled, the set of parameters describing a given situation is memorized (memorizing the context), and the control variable NK that informs of the need to establish communication is defined. For a given object there exists a possibility for a given object to fulfil premises launching more than one rule. Then, as a result of algorithm operation, we obtain sets of parameters describing a situation (contexts) requiring to start communication.

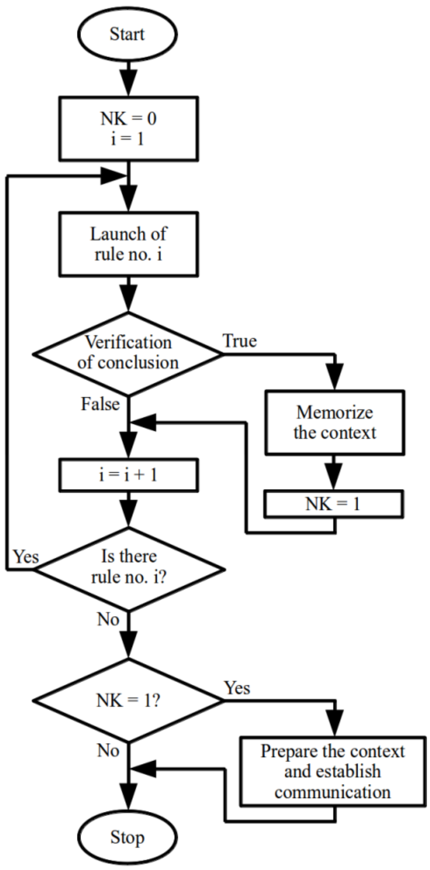

Fig. 1. An algorithm of the process of identifying navigational situations requiring communication to be established

Table 1. Examples of rules for the identification of navigational situations requiring communication to be established by a ship

No.	Premise	Conclusion	Remarks
1	External calling	Send a control to the received message analysis system	
2	Required distress OR urgency OR safety communication	Establish communication	Navigator's decision
3	Risk of collision exists AND I am NOT a give-way vessel	Establish communication	On the basis of CPA, TCPA and MPDM
4	Vessel is approaching the boundary of a reporting system or has crossed it	Establish communication	Boundary is set on the basis of a voyage plan or from information received from ECDIS system
5	Pilot is required for further manoeuvres	Establish communication	Based on voyage plan and navigator's decision

The algorithm shown in figure 1 is applicable to all objects that are essential for an analysis and assessment of own ship situation. That is why each rule can be launched many times. This refers to a situation when, for instance, there are two or more ships involved in a situation.

Individual rules are recorded in a knowledge base. Their form and order of launching may be adjusted so that the inference mechanism will be the same for various applications – the versions for ships and land-based centres differ only in the content of their respective knowledge bases. Presented in table 1 is a set of example rules intended for a ship.

Inference methods in a model of navigational situations identification

In the model of navigational situation identification, its inference module takes into account data (information) collected from available shipboard systems and information from the navigator, obtained after filling out of forms generated by the navigational situation identification system. These data are subject to formalization, using the computing with words. In the obtained form they make up premises in the process of inference. This, taking place at this stage, is restricted to inference with bivalent logic, that results in a message stating whether the existing navigational situation requires communication to take place.

The most frequently used rules of inference in the model are *modus ponens* and *modus tollens*, in which the implications used are derived from the knowledge base containing, among others, Collision Regulations [1] and values of parameters vital for safety (e.g. CPA_L and $TCPA_L$). One of the stages in navigational situation identification is an analysis of collision risk (compare section *Algorithmization of the navigational situation identification*). Based on the present values of CPA and TCPA and limit values CPA_L and $TCPA_L$ declared by the navigator, the system creates implications identifying situations, for which there is a risk of collision. On this basis a decision is generated through a subsequent implication on establishing communication or not. An example of inference scheme for point 10 of the checklist given in section *Algorithmization of the navigational situation identification* is as follows:

CPA, TCPA

If ($CPA < CPA_L$ and $TCPA < TCPA_L$ and $TCPA \geq 0$) Then A

If A Then B

B

where A denotes risk of collision, B denotes a need to establish communication. Similar schemes describe inference at other stages of the presented model of navigational situation identification.

The model of automatic navigational situation identification may be used in an automatic communication system in maritime shipping, exclusively for the identification of a situation that may require communication with another ship or a shore-based station, or for fully automatic execution of communication and negotiation mechanisms.

In the former case (identification), the module, made on the basis of the developed model, acquires and processes information needed for the assessment of a navigational situation, informing the navigator that communication has to be established and why. The latter case refers to automatic implementation of communication and negotiation mechanisms, for instance those in routine communication.

One example of the former case is when following the start-up of subsequent rules and conclusion verification, the outcome may be a message containing a notification on the need to establish communication due to a risk of collision. The notification might have this form:

ESTABLISH COMMUNICATION

RISK OF COLLISION with ship / object ....

CPA is .... (CPA_L=…), TCPA is … ($TCPA_L$=…)

The communication and negotiations are continued by the navigator, either orally or manually through a computer system.

The cause given in the example is *Risk of collision*, but it can be *Boundary of the reporting system*, *Distress or Urgency Communication.* Besides, a generated message may take a form of an instruction to fill out a form, e.g. data required by a VTS.

In the latter case the module executes the stage preceding automatic generation of messages (or their proposed texts), directed to external objects (ships, land-based centres). Then communication is performed in the semi-automatic or automatic mode, using the mechanisms of co-operation and negotiations concerning safe ship conduct. Based on the conclusions sent, the system generates and sends (automatically or when accepted by the navigator) a proper message to the other ship or shore station.

Conclusions

This article deals with a model of identifying navigational situations which require communication to be established between ships or a ship and a shore station. The model represents a system embedded in a larger system of automatic communication in maritime shipping and may have two functions: to identify a situation calling for communication with another ship or shore station, or to automatically implement mechanisms of communication and negotiations.

The automation of communication processes between ships and land-based centres may contribute to the limitation of human errors, such as failure to establish communication, misunderstanding a received message, improper choice of a message or wrong interpretation of exchanged information, thus it may contribute to enhancement of shipping safety.

The previously presented concept of marine automatic communication system and the herein presented model of identifying navigational situations requiring communication to be established by a ship fits into the concept of e-navigation, developed at the IMO forum. The concept includes standardization of navigational information and automation of information exchange processes.

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