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CONVERSATIONS PROCESSES IN THE SYSTEM OF AUTOMATIC COMMUNICATION AT SEA

Summary. The progressing automation of maritime transport, including the introduction of autonomous and/or unmanned ships, calls for the development of communication principles, particularly conversations currently carried out verbally. The work in this field is intended to improve the safety of maritime transport. This article describes research on automatic communication in the form that will support navigators responsible for ship conduct. The processes of inference and conversation management are described. The developed methods are based on standard marine communication phrases. The presented example conversation between navigators is supported by an automatic communication system. The work herein described aims at the creation of procedures for communication at sea between autonomous ships.
Keywords: autonomous ships, automatic communication, inference processes

1. INTRODUCTION

Navigational accidents, mainly collisions, have been analysed for years to identify the causes, learn lessons and thus enhance the safety of maritime transport [3, 4]. According to an annual summary of marine accidents and incidents, prepared by the European Maritime

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Safety Agency (EMSA) in 2017, the basic causes of accidents and incidents involve the human factor (Fig. 1).

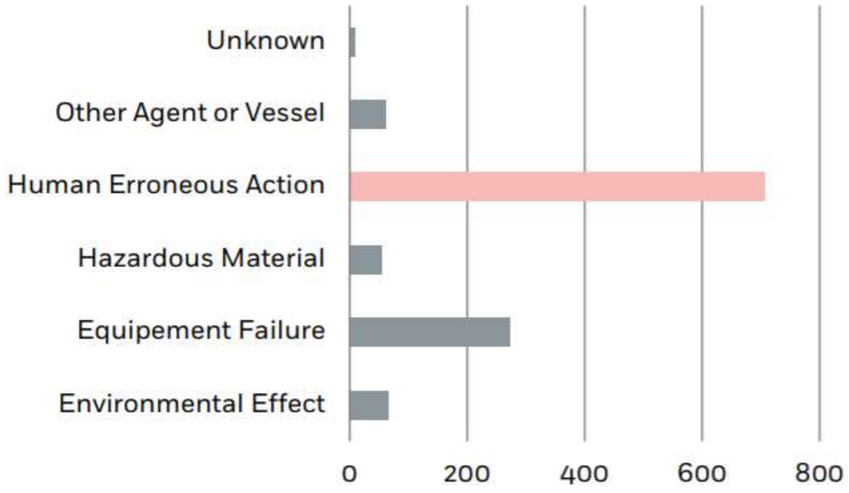

Fig. 1. Distribution of accident causes [1]

Of the overall number of investigated 1170 events, 60.5% were attributed to human error. Aimed at safety improvement, decision support systems have been dynamically developed to help ship navigators minimise the number of possible errors. One example of such systems, NAVDEC, operates in real-time and is handled by the navigator [6]. The system watches its ship and the environment and records information about the current navigational situation. Based on this, it identifies and assesses the navigational situation and generates solutions to ensure safe navigation.

Frequently during the encounter of ships, the navigators have to establish verbal communication to exchange additional information and agree on how to solve the collision situation. Unfortunately, difficulties such as reduced concentration, misunderstanding, stress and fatigue sometimes make the communication incorrect, thus posing risks of making wrong decisions. The problems with correct verbal communication are not only related to misunderstanding of a message due to insufficient knowledge of English and standard marine communication phrases. Other communication problems include:

- lack of communication,
- misinterpretation of the information received,
- failure to consider all necessary information due to its excess,
- wrong assessment of the navigational situation,
- wrong decision made.

These errors are made sometimes due to limitations of the human mind, as the human mind has limited ability to process and simultaneously use a large number of information items. The solution to this problem may be a system supporting communication or conducting it automatically.

2. COMMUNICATION PROCESSES AT SEA

What characterises voice communications at sea is that the sender and the receiver do not have the ability to use certain communication tools, such as facial expression, body language, while voice tone and timbre are limited due to equipment quality. The process of communication between people carries the risk of making errors related, inter alia, to incorrect reception and misinterpretation. Therefore, the developed principles of communication at sea hold that the messages sent should contain single pieces of information. To avoid misunderstanding, navigators are required to use standard marine communication phrases (SMCP) [2]. The SMCP was adopted by 22. Assembly of the International Maritime Organisation (IMO) in November 2001 as Resolution A.918 (22). Prior to the SMCP, standard marine navigational vocabulary had been developed for use by seafarers as an effect of the agreement that one common language - English - should be established for navigational purposes, where language difficulties arise. The SMCP was created as a more comprehensive, structured language covering all main verbal safety-related communications.

The SMCP contains words that were selected to cover the main safety-related ship-to-ship and ship-to-shore communications. The purpose of the SMCP was to address the problem of language barriers at sea and avoid misunderstanding that could cause accidents.

Unfortunately, many navigators fail to master the English language to a satisfactory level and/or possibly use standardised phrases in a comprehensible manner, which carries the risk of accident [7].

Therefore, it is purposeful to develop a system that could support navigators' communications.

3. THE SYSTEM OF AUTOMATIC COMMUNICATION

The developed system of automatic communication is an expert system enabling semi- or fully automatic communication, thus supporting the navigator conning the ship. In the case of semi-automatic communication, the generated message is displayed so that before sending it the navigator confirms the information contained in it. Any suggested actions resulting from the operation of the system are also presented to the navigator for his acceptance. In the fully automatic communication system, the navigator is informed of the generated and sent message and proposed actions, while the navigator's confirmation is not required (Fig. 2).

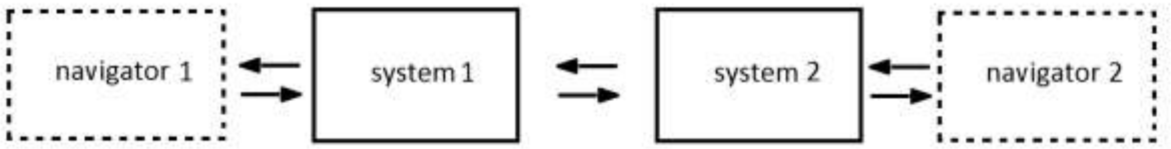

Fig. 2. System of automatic communication, ship-to-ship communication

The system of automatic communication is composed of four main modules:

- module of communication,
- module of navigational systems,
- COLREGs module,
- module of simulation of the navigational decision system.

The module of communication is the main element responsible for conversation implementation and management. Its operation is built on a knowledge base and an inference mechanism, both created by using experts' knowledge. Inference is executed following the manner of human reasoning, hence, the inference block of the communication module is a form of virtual navigator. The module of navigational systems is an element receiving data from shipboard systems. The module allows the automatic communication system to have access to the ship's data: speed, course, ship-manoeuvring parameters. Once the user interface is developed, the module will also display to the navigator the messages and suggested actions. The COLREGS module is responsible for the classification of the navigational situation based on applicable regulations. The module indicates if the ship has the right of way or not, while the simulation module of the navigational decision system calculates the manoeuvres to be performed by the navigators and, inter alia, the ships' trajectories are worked out and verified.

The correct functioning of the automatic communication system requires the development of procedures for the exchange of data between the said modules for the management of the conversation.

4. THE MANAGEMENT OF CONVERSATION

The exchange of data between the modules is created for inference processes. The notation of data exchange is this:

sender_receiver_action=value

In the above notation, the sender and the receiver are one element of the NO set, action is an element of the set D, while the value is one single element or the corresponding pair of the elements from the set W, defined as follows:

NO={KO, SYS, SIM, COL}, where KO – module of communication, SYS – module of navigational systems, SIM – module of the navigational decision system simulation, COL – module of the Collision Regulations.
W={parameter_set, parameter_set_value, trajectory, trajectory_value, maneuver, maneuver_value,…}
D={give, notify, update, request, demand, check, find, propose, warning,…}

Depending on the connection of the sender and the receiver, various actions with the corresponding values are possible.

The exchange of data between the module of navigational systems and the module of communication mainly includes communication related to the delivery of basic parameters (parameter_set, parameter_set_value) and manoeuvres (maneuver, maneuver_value) and communicating to the navigator requests from the other ship (for example, keep_course, keep_speed) (Tab. 1).

The exchange of data between the COLREGs module and the module of communication refers to the classification of the navigational situation, thus, the data that is exchanged is related to verification of which ship is the give-way vessel. The value give_way_true means that our ship, according to the regulations, is the give-way ship, and give_way_false means that our ship is not the give-way ship.

Tab. 1

Exchange of data between the KO and SYS modules (fragment)

Sender	Receiver	Action	Example values
SYS	KO	give	parameter_set
SYS	KO	notify	parameter_set, parameter_set_value
KO	SYS	give	parameter_set
KO	SYS	update	parameter_set, parameter_set_value
KO	SYS	request	keep_coursekeep_speed
KO	SYS	demand	maneuver_own_value, maneuver_other_value

Tab. 2

Exchange of data between the KO and COL modules (fragment)

Sender	Receiver	Action	Example values
KO	COL	classify	give_way
COL	KO	classify	give_way_true
COL	KO	classify	give_way_false

The most complex data exchange is the one between the KO and SIM modules, performed to establish required manoeuvres and trajectories of the ships. The manoeuvres and trajectories sent must be verified and confirmed, and if an agreement is not given for a proposed manoeuvre or trajectory, the reason designated P should be given as well as requirements (marked R) to be met by the new proposal, so the relevant notation is this: trajectory_other_value_false_P_R or maneuver_other_value_false_P_R (Table 3).

Tab. 3

Exchange of data between the KO and SIM modules (fragment)

Sender	Receiver	Action	Example values
KO	SIM	give	maneuver_own, maneuver_other
SIM	KO	notify	maneuver_own_value, maneuver_other_value
KO	SIM	check	trajectory_other_value maneuver_other_value
SIM	KO	check	trajectory_other_value_true maneuver_other_value_true, trajectory_other_value_false_P_R maneuver_other_value_false_P_R
KO	SIM	find	maneuver_R
SIM	KO	warning	trajectory_contradiction, speed_contradiction, course_contradiction, colision,
KO	SIM	update	maneuver_other_value

Based on the MMSI numbers, the names 'own' and 'other' are sent, enabling correct interpretation of the data.

5. AN EXAMPLE

Let us consider an encounter situation of two ships Alpha (A) and Beta (B), proceeding on collision courses. Additionally, let us suppose that the situation takes place in an open sea area and under good weather conditions. Aboard both ships, the automatic communication systems are in operation, ship B is the give-way vessel, and the situation is viewed from ship A (own ship). Let us examine an example scenario of a conversation that was held automatically between the systems of both ships, and a record of data exchange between the modules of the automatic communication system (Table 4).

As the ships approach each other, the communication is established to exchange basic parameters of the ships. A message is generated, containing information about the parameters of ship A. At the same time, a requirement is identified to obtain the parameters of ship B; therefore, a request for those parameters is generated too. The messages with the parameters are exchanged. Having these data, the system is capable of transmitting the need to identify the navigational situation to the COL module. Based on the Collision Regulations, it is determined that ship B is the give-way vessel, so it sends information about planned manoeuvres. The data on the manoeuvres are analysed using the simulation module, which confirms the consent to such actions of ship B. A message to ship B is generated along with information for the navigator of ship A.

Tab. 4

An example scenario of a conversation with data exchange

Lp	Exchange of data between the modules	Communication
1	SYS_KO_notify=parameter_set, parameter_set_value	A:tell,information, parameter_set, parameter_set_value
2	SYS_KO_give=parameter_set,	A:question,information, parameter_set
3		B:answer,information, parameter_set, parameter_set_value
4	KO_SYS_update=parameter_set, parameter_set_value	
5	COL_KO_classify=give_way_false	
6		B:tell,intention, maneuver_value
7	KO_SIM_check=maneuver_other_value	
8	SIM_KO_check=maneuver_other_value_tr	
9	KO_SYS_update= maneuver_other_value	A:tell, permission, maneuver_value

The outcome of the communication carried out in this way is a solution – safe, collision avoiding and clear for both ships.

6. CONCLUSIONS AND DIRECTION FOR FURTHER WORK

Human errors are a major cause of navigational accidents. The minimisation of their occurrence is the goal of many research teams. Today, attempts are made to develop and introduce marine autonomous and/or unmanned remotely supervised ships, which involves the elaboration of communication principles, particularly in reference to verbally conducted exchanges. This article contributes to the research on automatic communication, which has a form that supports ships' navigators. The data exchange executed between the elements of the automatic communication system was described and illustrated. The presented example conversation between the navigators illustrates the way the system is and will be developed. The system improves processes of communication, consequently, enhances the safety of maritime transport. Further work on the automatic communication system should focus on procedures for communications on sea-going autonomous and/or unmanned remotely supervised ships.

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